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THE DISTRIBUTION OF THE FORMS OF SULPHUR IN THE COAL BED

BY

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AND

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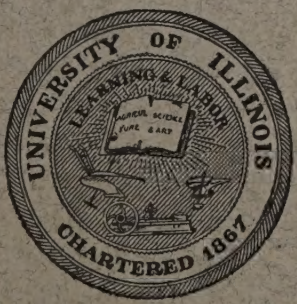
Illinois Coal Mining Investigations Coöperative Agreement

(This Report was Prepared under a Coöperative Agreement between the U. S. Bureau of Mines, the Engineering Experiment Station of the University of Illinois, and the Illinois State Geological Survey Division)



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THE Engineering Experiment Station was established by act of the Board of Trustees of the University of Illinois on December 8, 1903. It is the purpose of the Station to conduct investigations and make studies of importance to the engineering, manufacturing, railway, mining, and other industrial interests of the State.

The management of the Engineering Experiment Station is vested in an Executive Staff composed of the Director and his Assistant, the Heads of the several Departments in the College of Engineering, and the Professor of Industrial Chemistry. This Staff is responsible for the establishment of general policies governing the work of the Station, including the approval of material for publication. All members of the teaching staff of the College are encouraged to engage in scientific research, either directly or in coöperation with the Research Corps composed of full-time research assistants, research graduate assistants, and special investigators.

The volume and number at the top of the front cover page are merely arbitrary numbers and refer to the general publications of the University of Illinois; *either above the title or below the seal is given the number of the Engineering Experiment Station bulletin or circular which should be used in referring to these publications.*

The present bulletin is issued under a coöperative agreement between the Engineering Experiment Station of the University of Illinois, the State Geological Survey, and the United States Bureau of Mines. The reports of this coöperative investigation are issued in the form of bulletins by the Engineering Experiment Station, the State Geological Survey and the United States Bureau of Mines. For bulletins issued by the Engineering Experiment Station, address Engineering Experiment Station, Urbana, Illinois; for those issued by the State Geological Survey, address State Geological Survey, Urbana, Illinois; and for those issued by the United States Bureau of Mines, address the Director, United States Bureau of Mines, Washington, D. C.

ERRATA

, par. 2, line 7: *for* "mine" *read* "nine."
, line 1: *for* "certified" *read* "confirmed."
, lines 10 and 12: *for* "1.30(1.00–x)5x" *read* "1.30(1.00–x)+5x."
, par. 2, line 5: *omit* "and the dotted line fine disseminated pyritic sulphur."
data on fine disseminated pyritic sulphur see Tables A, C, G, J, P,S,and Appendix I.
, line 4: *for* "Fig. 6" *read* "Fig. 5."
, lines 2 and 3: *for* "Fig. 6: A, B, C, D, E, and F, and Fig. 7: G, H, I, J, and L" *read* "Fig. 6: A, B, C, D; Fig. 7: E, F, G, H; and Fig. 8: I, J, K,

par. 4, line 3: *for* "Fig. 13, U, and V" *read* "Fig. 13, T, and U."
[redacted] "on moisture-free basis" *read* "on 'as received' basis."
lines 5 and 6: *for* "Fig. 1, Charts A, B, C, D, E, and F, and in Fig. 2, rts G, H, I, J, K, and L" *read* "Fig. 6, Charts A, B, C, and D; Fig. 7, rts E, F, G, and H, and Fig. 8, Charts I, J, K, and L."

UNIVERSITY OF ILLINOIS
ENGINEERING EXPERIMENT STATION

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THE DISTRIBUTION OF THE FORMS OF SULPHUR IN THE COAL BED

BY

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Table 6: *fo*

ENGINEERING EXPERIMENT STATION
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THE DISTRIBUTION OF THE FORMS OF SULPHUR IN THE COAL BED

I. Introduction

1. *Preliminary Statement.*—This bulletin is a report of investigational work carried out by the United States Bureau of Mines under the terms of a coöperative agreement with the Engineering Experiment Station of the University of Illinois and the Illinois State Geological Survey. Previous work published by the Engineering Experiment Station on the forms of sulphur in coal was conducted in the Chemical Laboratory of the University of Illinois by S. W. Parr and A. R. Powell, who developed successful methods for determining quantitatively the different chemical forms of sulphur in coal. Their methods, described in a previous bulletin,* have been applied in the present work to the study of the manner of occurrence and distribution of the different forms of sulphur in the coal bed.

2. *Object of the Work.*—The experimental work was undertaken as a part of the United States Bureau of Mines plan of research on coal preparation, and the application of the information secured to the problem of producing cleaner coal was the principal objective. The solution of this problem must of necessity rest to a considerable extent upon an intelligent knowledge and appreciation of the physical and the chemical forms in which sulphur occurs in a particular coal, and how it is distributed through the coal in the bed. This information is essential in forming an opinion on the extent to which any given coal may be cleaned by washing, that is, by a gravity separation in water. The forms of sulphur occurring in the coal are sulphur as iron pyrite, sulphur in organic combination with the coal substance itself, and sulphate sulphur present chiefly as calcium sulphate. Pyrite occurs both in macroscopic and microscopic form.† Thiessen has found microscopic globules of pyrite in coals from many different fields in the United States, and even in peat. Pyrite has also been known to exist in this form in Japanese‡ coals.

* "A Study of the Forms in which Sulphur Occurs in Coal," Univ. of Ill. Eng. Exp. Sta., Bul. 111, 1919.

† Am. Inst. Min. Eng., Bul. 153, 2431, 1919.

‡ Iwasaki, Colliery Guardian 120, 797, 1920.

Pyrite or pyritic sulphur is not uniformly distributed in coal. It is well known that the variation in total sulphur content of the different benches or horizontal sections of a coal bed may be quite marked. This of course might be entirely due to the heterogeneous distribution of iron pyrite. The distribution of organic sulphur has been given but little attention, because it exists in an amicroscopic form and must be determined by chemical methods. Until recently no satisfactory methods have been available. Some earlier work,* done since the publication of Parr and Powell's methods, led to the tentative conclusion that the organic sulphur content of a given coal varies but little, and that, at least, it is much more uniformly distributed than pyritic sulphur. The distribution of these forms of sulphur has an important bearing on the practice of coal washing, the dry separation of impurities from coal, and the use of coal for coking purposes.

The fact that organic sulphur has some bearing on the washability of a coal has long been recognized. Some coal washing reports have contained an approximation of the figure for the percentage of this form of sulphur, in some cases with fine pyrite included under the caption "fixed sulphur," "combined sulphur," or "organic sulphur." Bolling,† in a paper on "Chemical Control of Coal Washers" describing methods used at the plant of the Nova Scotia Steel and Coal Co., gives the following figures determined by a sink and float test on a calcium chloride solution of 1.35 specific gravity: "Raw coal mixture, total sulphur 2.30 per cent; by calcium chloride, total sulphur 1.10 per cent; (2.30 – 1.10) = 1.20 per cent pyritic sulphur, organic sulphur 1.10 per cent." While this method does not give the correct values for organic sulphur, it does give a figure which is of value in coal washing work.

Carl Wendell,‡ in an article on coal washing, states concerning combined sulphur that many times in examining a new washing apparatus he had been assured by the manufacturer that the machine would produce the desired results, this conclusion being based on two figures only; namely, total sulphur content of the coal and combined sulphur content. Wendell adds further, "Invariably I have found that this premature statement was wrong."

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* Fraser and Yancey, Am. Inst. Min. Eng., Bul. 153, 1822, 1919.

† Eng. and Min. Journal, Aug. 29, 1908.

‡ Univ. of Ill. Technograph, page 133, April, 1915.

His comment concerning the value of such hastily formulated ions is fully warranted. The instances cited indicate that in some s organic sulphur has been one of the factors considered in con- ion with the reduction of sulphur in coal by washing processes. the other hand the opinion is sometimes expressed that the organic hur of coal is negligible in amount. There is a need for more rate and specific information on this subject.

It is apparent that the possibility of cleaning coal of sulphur processes of dry separation such as selective mining, hand picking he face and in the tipple, or by mechanical devices, depends upon way in which the sulphur, particularly the pyritic sulphur, is ributed throughout the coal.

This factor also has an important bearing in connection with coking of coal. Uniformity of sulphur content is a valuable ibute of a coal to be used for coking or for gas manufacture. Some he Illinois mines nominally rated as low sulphur coal mines cannot depended upon to ship day in and day out a product consistently in sulphur.

All of the mechanical or gravitational methods of cleaning coal end upon the removal of particles of impurities of high specific vity from coal which is of lower specific gravity. In this connection s important to know whether organic sulphur segregates as does itic sulphur. In case concentrations of organic sulphur were found xist it would be desirable to associate such occurrences with other urities or specific recognizable conditions.

3. *Sources of Information.*—The observations set forth in this tin are based on data secured by:

1. Visual examination and sampling of coal in situ at mines in three different beds in the central district; namely, Illinois No. 6 Coal at the Middlefork Mine of the United States Fuel Company at Benton, Illinois, and Kentucky beds No. 9 and No. 12 at mines No. 7 and No. 8 of the West Kentucky Coal Co. in Union and Webster Counties of western Kentucky. Sectional bench samples were taken in a number of places in each of these mines and analyzed for total sulphur, organic sulphur, pyritic sulphur, and fine disseminated sulphur.

2. Investigations incident to a survey of the coal pyrite resources of the central district, made by the United States Bureau of

Mines and the State Geological Surveys of Illinois, Indiana, Ohi Tennessee, Missouri, and Iowa, in 1918. A large number of min were visited by the field men sent out by these agencies. Not were taken on the occurrence of sulphur, and estimates were mad of the available tonnage of pyrite which could be recovered an cleaned for industrial uses. The records of this work present qui a fund of information on the distribution of coarse pyrite in th various coal beds throughout the district.

3. Visual examination of the coal faces in mines in con nection with other investigational work and routine face sam pling.

4. *Acknowledgments.*—The investigation was carried out unde the general direction of Mr. E. A. Holbrook, Assistant Directo and Mr. George S. Rice, Chief Mining Engineer, of the United State Bureau of Mines. Professors S. W. Parr, Head of the Division of In dustrial Chemistry, and H. H. Stoek, Head of the Department o Mining Engineering of the University of Illinois, have contributed man helpful and valuable suggestions throughout the course of the work Mr. C. A. Meissner, Chairman of Coke and Coal Washing Committee of the United States Steel Corporation, has followed the progress o the investigation with cordial coöperation. Messrs. W. H. Clinge man, President, and Thomas Moses, General Superintendent, of th United States Fuel Co., made the arrangements for the work at th Middlefork mine, and through their local organization at the mine gav every assistance. Mr. D. M. Lewins, Chemist of the United States Fu Co. at the Middlefork mine, rendered valuable aid. The field work o western Kentucky coals was carried out at mines of the West Kentuck Coal Co., aided by the active coöperation of Mr. T. E. Jenkins, Vic President and General Manager of this Company.

II. General Data on Sulphur Distribution

5. *Chemical Forms in which Sulphur Occurs in Coal.*—Sulphur urs in coal in both organic and inorganic combination. In the ıtral and eastern coal fields of the United States the major inorganic phur compound is iron pyrite or marcasite, both of identical chem- l composition. Sulphate sulphur is ordinarily present in freshly ıed coal chiefly as calcium sulphate, (gypsum), occurring in thin ite flakes along the cleavage planes. Calcite also occurs in a similar m. Because of the marked color contrast between the gypsum and coal an exaggerated idea of the relative amount of the total sulphur sent in the sulphate form is easily given. Freshly mined coal may tain as much as 0.1 per cent sulphur as sulphate, but as a rule the ount of this form is less than 0.05 per cent. Stored coal increases ulphate sulphur because of the oxidation of its iron pyrite. Length storage, temperature, moisture, and the size of coal stored appear be the principal factors governing the rate of oxidation and the sequent formation of sulphate sulphur, so that after long storage sulphate sulphur content may exceed that of the pyritic sulphur. s sulphate sulphur is water-soluble and if the coal is stored in the n a large part will be leached out.

It has long been believed that a varying though considerable portion of the total sulphur content of coal is present in organic bination with the coal substance. The investigations of Wheeler of many other workers have confirmed this view. Prior to 1873 rmley* observed that some coals contained too little iron to combine ı all the sulphur present to form iron pyrite. He gives total hur and total iron determinations of mine coals, and in no case fficient iron present to unite with all of the sulphur as ferric sul- le. The investigations of Bradbury,† Kimball,‡ Drown,¶ Fischer,§ allum,** Parr,†† Powell,‡‡ and Wibaut and Stoffel¶¶ have

* Geol. Survey of Ohio, 1, 361, 1873.
† Chem. News, 38, 147, 1878.
‡ Trans. Am. Inst. Min. Engr., 8, 185, 1880.
¶ Trans. Am. Inst. Min. Engr., 9, 656, 1881.
§ Zeit. angew. Chem., 764, 1899.
** Chem. Engr., 11, 27, 1910.
†† Univ. of Ill. Eng. Exp. Sta., Bul. 111, 1919.
‡‡ J. Ind. Eng. Chem., 12, 887, 1920.
¶¶ Rec. trav. chim., 38, 132, 1919.

certified the existence of sulphur in organic combination in coal. appears that the organic sulphur is united with two different ty of coal constituent, and is classified as humus organic sulphur a resinic, or perhaps more properly merely as phenol soluble sulphur.

6. *Physical Forms of Pyrite.*—Iron pyrite may be found in c in particles of various sizes and various shapes. Thiessen,* throu the microscopic study of thin sections, found that all the coals examined contained very small globules or particles of pyrite varyi in diameter from a few microns to a hundred microns. At the ot extreme it is not uncommon to find, in the roof slate of the No coal in Indiana, pyrite boulders several feet in diameter. For purpose of studying the distribution of the pyrite in coal it has b found convenient to classify it according to the size of particles which it occurs, under three headings, namely, microscopic pyrite, f disseminated visible pyrite, and coarse pyrite. The lines of divisi into these groups are of course merely arbitrary. As the partic exist in the bed they grade in size all the way from the very small to the largest.

The microscopic pyrite consists of minute spherical globules visible except under the microscope. This form of sulphur is removable by mechanical processes.

The fine disseminated visible pyrite occurs in several for This term is used to designate pyrite infiltrations coarse enough to visible to the naked eye, yet so fine and intimately mixed with coal substance that their separation is difficult. Thin film-like co ings sometimes occur on the joint planes, giving a natural cleava face of a lump of coal the appearance of being gold painted. fraction of a per cent of sulphur in this form may make a car of c look very dirty. Pyrite may occur in the form of small grains d seminated through the coal. Charcoal or mother-coal is sometim so thickly impregnated with pyrite grains of this sort that it has brownish color and is so hard that it interferes with the use of und cutting machines. The miners call this material "black jack." Cl and shale partings may also be impregnated with pyrite particles the same manner.

The coarse pyrite occurs in a wide variety of shapes, the m common of which is perhaps the lens; circular or elliptical in plan a

* Loc. cit.

nticular in cross section, thick in the center and gradually thinning an edge around the perimeter. These lenses are commonly from in. to 3 in. in greatest thickness and about 1 ft. across, although nses as much as 3 or 4 ft. thick and several hundred feet long e sometimes found at the top or bottom of a seam. In some ds the small lenses occur always at the same horizon along certain dding planes. They may be almost edge to edge, forming a prac-ally continuous sheet of varying thickness. In other cases the nses are distributed promiscuously through the bed and may be und in any position.

Another somewhat similar form of pyrite deposit, much less mmon, is thinnest in the center with the thick part near the cir-lar rim.

Balls or nodules of sulphur are roughly spherical in shape. This rm is often found in the roof or floor. The term nodules is usually plied to the small ones of 2–4 in. in diameter. The larger sizes e more often called niggerheads or balls. Where they occur in e roof they are sometimes 4 or 5 ft. in diameter. The large es quite often consist of a mixture of iron carbonate and pyrite they may have a core of limestone with a pyrite shell. The all nodules are usually bright crystalline pyrite and approach more sely pure iron pyrite (FeS_2) in chemical composition. Pyrite posits which appear as continuous bands in a working face may be scribed as flat lenses of great lateral extent, such that they may continuous over large areas. They commonly vary from the thick-ss of a knife edge up to 2 or 3 in. Locally, thin parallel nds sometimes occur interlaminated with thin bands of coal in h a manner as to necessitate picking out and discarding a large portion of coal with the pyrite. Similarly with the thin facings coal described under fine disseminated pyrite, large lumps of coal metimes are so thickly impregnated with these film-like flakes of rite as to justify discarding the lumps as a whole.

Pyrite also occurs in vertical or inclined veins in some coals hough this form is not very common. The thicker and more prom-nt veins are called by the miners "spar sulphur."

Local groups of veinlets that appear to arise from a common ter are called cat-faces. The center is often a small ball of irreg-r outline. The pyrite of cat-faces is a brassy yellow in color and en of a flaky porous structure. Bands of pyrite of a similar porous

or cellular structure are commonly found in Southern Illinois coal. A lump of such forms seems to be built up of small thin plates of pyrite put together with spaces intervening so that the apparent specific gravity of the whole lump is much lower than that of a piece of solid pyrite. Apparent specific gravity determinations on samples from the No. 6 bed in Franklin County, Illinois, gave results as low as 2.9.

Pyritized vegetable fossils are not uncommon although they do not constitute any considerable part of the pyrite of coal. They are usually in the form of fragments of branches or leaves.

The manner in which the pyrite in any coal occurs in these various forms determines to a large extent the ease with which it may be separated from the coal by handpicking or washing. Solid balls and lenses of the massive amorphous structure and brassy color are readily removed underground as they are easily seen and they usually break freely from the surrounding coal. Lenses of a dark stony gray color are not so easily picked out at the face. They are much more difficult to see and, as the boundary between coal and pyrite is usually indefinite, the lens stick fast to the coal.

Of the interbedded continuous bands, those which are solid clear pyrite usually separate easily from the coal along a natural bedding plane. Sometimes the coal and pyrite fall apart during mining. Bands of this sort which are ½ in. or more in thickness are usually left in the mine. Thinner bands are broken up in shooting down the coal so that fragments become mixed with the coal and are difficult to pick out. A washer, however, will remove these small pieces.

The grey laminated bands are much more difficult to remove. There usually is no natural cleavage between the band and the adjacent coal. The thin laminae of pyrite merge indistinguishably in the coal and it is necessary to discard a large amount of adhering coal in order to get rid of them by picking. If this material is sent to the washer, a large proportion of the pyrite is slimed in crushing, which increases the difficulty of its removal by washing.

This is also true of the cat-faces and pyrite facings in joint cracks. In order to improve the appearance of a car of coal, lumps which contain only two or three per cent sulphur in this form are sometimes discarded in the tipple. These cat-faces and pyrite facings are the most troublesome visible forms of sulphur for the washerman. When the coal is crushed for washing, even as fine as ¼-in. size,

ge part of this sulphur adheres to the coal particles, and a large rt of that which breaks free is slimed or broken into thin scales ich have a tendency to float off with the washed coal.

The impregnations of fine grains of pyrite are of course inseparably mixed with the coal. All the coals used in the coal washing ts at Urbana were found to contain a considerable proportion of ritic sulphur in this form. Samples of coal, finer than 1/8-in. maxium size, carefully hand-picked to eliminate all pieces showing a trace impurity on the surface, still contained pyritic sulphur. Analyses three such samples of a Williamson County, Illinois, coal are given Table 1.

TABLE 1

PYRITIC SULPHUR IN HAND-PICKED SAMPLES OF A WILLIAMSON COUNTY, ILLINOIS, COAL

Values given in table in per cent, on a moisture-free basis

Sample No.	Ash	Pyritic Sulphur	Total Sulphur
1	3.58	1.27	2.06
2	4.82	1.06	1.86
3a	4.27	0.84	1.63

Float on solution of 1.3 sp. gr.

7. *Distribution of Coarse Pyrite in Various Beds.*—If a large portion of the sulphur in a coal is concentrated in lenses, balls, , of solid pyrite, it may be possible by careful picking in the mine tipple to ship a low sulphur product even though the sulphur tent of the coal in the bed may amount to several per cent. Ordiily, however, coals which contain a large amount of coarse pyrite also high in organic and finer pyritic sulphur. The distribution he coarse pyrite in the bed is also of importance; for instance, if, ughout the mine, the lenses and balls are concentrated at a certain nite horizon, or if a certain bench contains a much larger perage of sulphur than the rest of the seam, hand-picking or selective ing is facilitated.

In some of the Central District coal seams the manner of distution of iron pyrite deposits in the bed is well defined and typical the entire area of the seam.

Balls or nodules in the roof and extending down into the top coa are characteristic of the Illinois No. 5 seam practically throughou the district in Indiana, Illinois, and Kentucky. Often there is a dis continuous band of pyrite lenses about the middle of this bed.

The No. 6 coal in Illinois naturally divides itself into thre benches. The top coal and the bottom coal each comprising from on eighth to one sixth the thickness of the bed are separated from th middle coal by definite persistent partings, the upper one usually c mother-coal and the lower one, called the blue band, of shale some times impregnated with pyrite. As a rule the narrow upper and lowe benches contain the larger part of the pyrite of the seam.

In the No. 2 coal of the Longwall district of Illinois the sulphu balls and lenses are confined largely to the upper half of the bed.

In the Danville district, where the No. 7 coal is mined, pyrit is usually in the form of lenses of the gray stony variety. They ar distributed promiscuously through the bed.

Some interesting notes on the coarse pyrite deposits of the Ohi coals are given by W. M. Tucker* who did the field work in that stat in connection with coal pyrite survey of 1918. The Middle Kittann ing No. 6 coal contains everywhere a parting near the middle of th bed of pyrite or shale, known as the middle band. This seam in Perr County, Ohio, shows a band of lenses about 13 in. from the top o the coal. In the Upper Freeport No. 7 coal, deposits of pyrite in th form of large boulders are found imbedded in the coal along the side of the sandstone horsebacks.

* Economic Geology, 14, 198, 1919.

III. Field and Laboratory Methods

8. *General Plan of Investigation.*—In outlining the plan for work it seemed that the only way to study the distribution of the ns of sulphur in the coal bed was to take sectional samples of the izontal benches of the seam in the mine at the working faces. So this plan has been extended to the examination of three beds of coal; No. 6 bed in Illinois and the No. 9 and No. 12 beds in Kentucky. as not been possible to study each bed at more than one mine, it is hoped that the No. 6 bed in Illinois may be examined in ral other localities, in order to determine whether there is a char- ristic distribution of the forms of sulphur throughout the bed. iously then, the results here given for the beds examined at one tion are not representative of the entire bed with regard to sul- r content, and must not be so interpreted.

The Illinois No. 6 bed was sampled at the Middlefork mine of United States Fuel Co., near Benton, Franklin County, Illinois. rge and excellently equipped washery* is maintained at the mine washing the entire output. The daily tonnage varies from 2400 800 for the mine, and the washery operates about ten shifts per . The washed coal is used for metallurgical purposes.

In Western Kentucky the No. 9 and No. 12 beds were examined; No. 9 bed in Union County at Mine No. 8 and the No. 12 bed in ster County at Mine No. 7 of the West Kentucky Coal Co. The 12 coal, a fairly low sulphur coal, is used extensively as a gas coal also as smithing and steam coal. The bed No. 9 coal is much er in sulphur, and finds sale chiefly for domestic and steam pur- s.

At each mine the seam was divided into horizontal benches, and bench was sampled separately, beginning at the bottom and con- ng to the top of the seam. This information was desired not only ow the distribution of the forms of sulphur in the bed, but also he purpose of determining whether a relation existed between ic and organic sulphur. Additional data on the possible rela- hip was secured by taking additional samples at places in the

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J. R. Campbell, Am. Inst. Min. Eng., Bul. 153, 1779, 1919.

mine which showed the coal intergrown with lenses, bands, and ca faces of pyrite in such a manner that none of the coal was mo than 1 or 2 in. distant from the pyrite itself. At the Middlefo mine seven tipple samples were obtained, each representing a day output of about 2500 tons of raw coal. A sample of the washed co representing one day's operation of the washery was taken in ord to secure information as to the form or forms of sulphur eliminat by a mechanical process such as washing. Two samples of mother-co were taken at the Middlefork mine. Determinations of total pyrit and organic sulphur were made on all of these samples, and the resul are shown, both graphically and in tabular form, in this bulletin.

In addition to the samples taken for chemical analysis, six we secured in the Middlefork mine for examination of the microscop pyritic sulphur. These were taken at the middle and near the top the seam. Microphotographs of thin cross-sections of these sampl are given. A small development map showing where the sampl were taken in the Middlefork mine is included. A table showing t pyritic and organic sulphur content of several eastern and centr district coals is included for the purpose of giving an idea of t relative amounts of these important sulphur forms contained various coals.

A new form of float and sink apparatus for use in making tes on fine coal has been developed and is described in this paper. was used in determining the amount and the variations of fine d seminated pyrite in the bench samples from two of the mines.

9. *Method of Collecting Samples.*—The face samples we taken by the Bureau of Mines method for sampling coal in t mine.* A vertical channel about 4 in. wide by 3 in. deep w cut in a clean fresh face, and the resulting cuttings caught on canvas. At each place selected for sampling the face was marked o before cutting the sample, into from four to eight horizontal benche and each bench was sampled separately, beginning at the floor. Ea sample was broken up with the mortar and pestle of the Bureau Mines sampling kit, then screened and reduced to 4-lb. size coning and quartering. In the Middlefork mine a portable ha crusher† was used to reduce the coal to a size small enough to perm

* J. A. Holmes, Bureau of Mines, Technical Paper No. 1.

† S. W. Parr, Illinois Geological Survey, Bul. 29, 19, 1914.

duction by coning and quartering. It crushes the coal to about -in. maximum size. The crusher is of the burr type, made of uminum and steel, with detachable handle and legs.

Fig. 1 is a photograph of the coal face in the No. 6 Illinois bed d is introduced to give a better idea of the method of sampling ed. The total thickness of the bed was first measured. Then the vision of the seam into benches was indicated by white horizontal alk marks made on the coal face. In the Middlefork mine, No. 6 bed, e seam was divided into from four to eight benches at the sampling ations, and each bench was sampled separately. Sectional bench nples were collected in this manner at twelve working faces in the ne. The top sample represents in most cases the first 10 or 12 of coal down to the natural bedding plane. The miner desig- tes this bench as the top coal. The bottom sample represents the l from the floor up to, but not including, the blue band. This nd, sometimes shale and often pyrite of a thickness of 2 or 3 in. nerally occurs from 10 to 15 in. above the floor. The intervening rtions of the bed were divided into from two to six sections, king the divisions, wherever practicable, at natural partings. e blue band was always thrown out. With this exception the nples cover everything from the top to the bottom of the seam, l represent fairly what is hoisted and sent to the washer. Tables to L in Appendix I give the vertical thickness of the horizontal tions, show the impurities occurring in a section, and indicate ether they were included in the sample.

In the mine operating in the No. 12 bed in western Kentucky, nples were taken at six locations. Here 1 to 2 ft. of the top l is left up for roof. This was sampled at two locations in the mine, l the remainder of the seam was divided into four approximately ual benches, represented by a corresponding number of samples. e division into benches was made in such a manner as to include one sample all of a characteristic shaly band occurring a little below middle of the seam. In the No. 8 mine of the West Kentucky Coal , which operates in the No. 9 bed, the seam was divided into four rly equal benches, four samples being taken at two locations.

The samples of raw coal, washed coal, and refuse were taken in manner prescribed for the sampling of deliveries.* The gross

* G. S. Pope, Bureau of Mines, Tech. Paper 133, 197.

samples were collected by taking shovelfuls at twenty minute inter
from the raw coal, washed coal, and refuse conveyors, respectively.

10. *Preparation of Samples for Analysis.*—The 4-lb. samp
were allowed to air dry in the laboratory. They were then crushed
¼-in. size and a sample cut out for the sink and float test. The f
samples, crushed in the Braun disc pulverizer to pass a 100-m
screen, were put into 4-oz. glass bottles sealed with rubber stopper

11. *Methods Used for Determination of Forms of Sulphu*
Total sulphur determinations were made by Eschka's method, wh
is so extensively used for estimating total sulphur in coal tha
description of the analytical procedure need not be given here.

The pyritic sulphur was determined by the method of Parr
Powell* by extracting 1 gm. of 100-mesh coal with a mixture
20 cc. of concentrated nitric (sp. gr. 1.42) and 60 cc. of water. T
dilute nitric acid has a specific gravity of 1.12. It is allowed to coo
room temperature before starting the extraction. The extractio
best conducted in a 300 cc. Ehrlenmeyer flask. Some coals are diffi
to "wet" by the dilute nitric acid, but by stoppering the flask
shaking vigorously for a minute, this is readily accomplished.
extraction process was always allowed to proceed for four days
room temperature; a vigorous shaking being given the flask once
twice each day during the period.

After extraction, the coal was filtered off and the filtrate ev
orated to dryness on the water bath. The residue was then dissol
in about 5 cc. of 1 to 1 hydrochloric acid, diluted with water to ab
100 cc., brought to the boiling point, and filtered. Ordinarily,
pyritic sulphur determinations were made by determining the sulp
in the filtrate rather than the iron, but determinations of both i
and sulphur were made on several samples from each mine in or
to find if iron and sulphur were present in the same ratio as in i
pyrite. The values obtained by calculating the sulphur from the i
and by determining sulphur direct, agreed very well indeed for
coal from each of the beds.

Organic sulphur was not directly determined. The values sh
for this form of sulphur represent the difference between the t
and the pyritic sulphur.

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* Loc. cit.

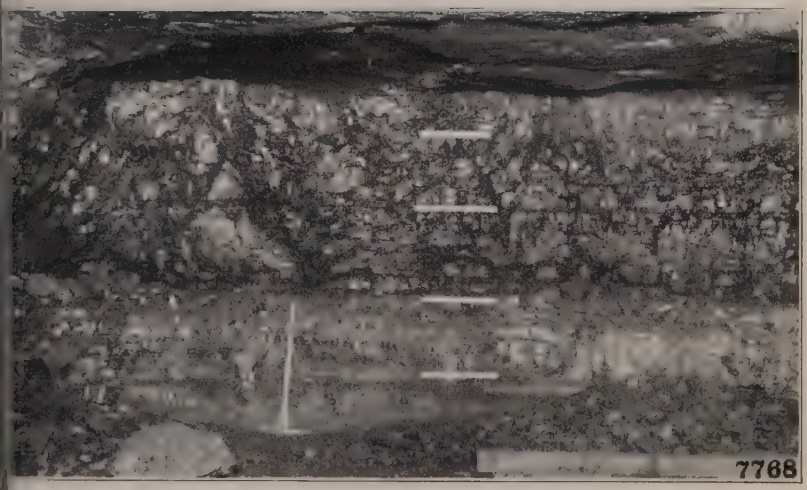

FIG. 1. FACE OF COAL IN ILLINOIS NO. 6 BED, SHOWING DIVISION OF SEAM INTO BENCHES FOR SAMPLING

Sulphate sulphur was found to be so low in the samples examined at it has been entirely disregarded in tabulating the variations of e forms of sulphur in the coal bed. Only ten samples were examined sulphate sulphur. It was extracted by boiling 5 gms. of coal one hour with 50 cc. of hydrochloric acid (sp. gr. 1.2) diluted to 0 cc. with water. The filtrate was evaporated nearly to dryness, uted, and the sulphates precipitated by adding an excess of a 10 r cent solution of barium chloride in the manner prescribed in the chka method for total sulphur. The highest value obtained for phate sulphur in the samples was 0.04 per cent, and this value s on a sample containing six per cent of total sulphur which had en mined three months.

12. *Determination of Fine Pyritic Sulphur.*—The term fine disinated pyritic sulphur is used in this report to designate fine pyrite rticles so intimately mixed with the coal that they are not broken e from it by crushing to the finest size at which coal is ordinarily shed, namely, through ¼-in. round hole screen; and sufficiently all not to render the coal particles in which they happen to occur avy enough to be separable by gravity methods. This is an abitrary inition which seems perfectly logical from the practical view point connection with coal washing. The determinations were made by jecting samples of the coal, of ¼-in. maximum size, to sink and at tests using a zinc chloride solution of a specific gravity 0.05 her than the average specific gravity of the coal, analyzing the float tion for pyritic sulphur, and correcting for the weight of sink moved in order to express the results as a percentage of the original coal sample for comparison with the other analytical data.

As determined by this method the figure for fine disseminated itic sulphur percentage does not account for all pyrite particles ow any certain fixed size, as some very small pieces, notably of the m which occurs as thin plates in the tiny joint cracks of the coal, may broken free from the coal and, sinking in the float and sink bath, be s discarded, while other pieces, possibly larger, which stick fast to or included in coal particles, may float. The size of the largest pyrite ticle which could be included may be calculated as follows; assumthe extreme case of a fragment of the maximum size in the sample sisting of clean coal with an attached or included pyrite particle t large enough to increase the specific gravity of the piece by 0.05,

and assuming that the specific gravity of the clean coal is 1.30, t
specific gravity of the raw coal particle in question is then 1
+ 0.05 = 1.35.

Let x = volume of pyrite in this raw coal particle of unit volu
1.00 = total volume of the raw coal particle.
1.00 – x = volume of the clean coal part.
1.30 (1.00 – x) = mass of the clean coal part.
5x = mass of the pyrite part, assuming specific gravity of pyr
as 5.00.

Then 1.30 (1.00 – x) 5x = total mass of the raw coal particle.
Also 1.35 = total mass of the raw coal particle.

$$1.30\ (1.00 - x)\ 5x = 1.35.$$
$$3.7x = 0.05.$$
$$x = 0.0135 \text{ volume of pyrite part of raw coal particle.}$$

$\sqrt[3]{0.0135} = 0.26$ size pyrite cube in unit cube of raw coal.

0.26 × ¼ in. = 0.065 in. size of maximum pyrite cube in ¼-in. cu
of raw coal.

0.065 in. = 10 mesh.

Sixty-five thousandths of an inch in diameter, or through 10-me
screen, therefore, is the maximum size of pyrite particle that could
included in the float part of the sample in determining fine pyr
sulphur by this method.

For making the determinations a new sink and float apparat
illustrated in Fig. 2 was used. This was designed for use in the c
washing laboratory for control work and preliminary testing wh
small coal is being handled. For coarse coal of jig size the apparat
developed some years ago by G. R. Delamater is used. This has be
very widely used for coal washery control and the method has prov
very satisfactory for the size of coal ordinarily washed in jig washe
In fact it is often referred to as the "Standard" sink and fl
apparatus.

In working with small coal, such as some washeries are n
handling, through a ¼-in. screen, or through a ⅛-in. screen with
large proportion of slime, and in experimental work in oil coagulati
and flotation of coal, where even smaller sizes are handled, a need h
arisen for an apparatus in which all the solution used as well as t
coal sample is divided into a float portion and a sink portion, and ea
screened or filtered with the respective float and sink portions of t
coal sample.

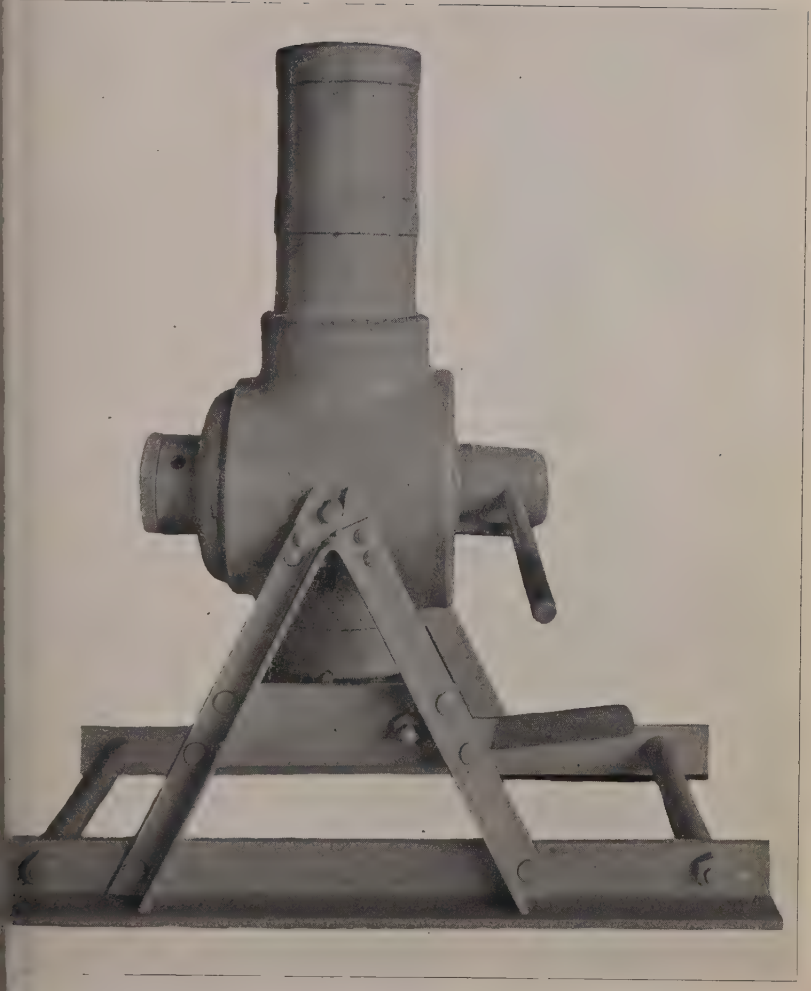

Fig. 2. New Sink and Float Test Apparatus, Assembled

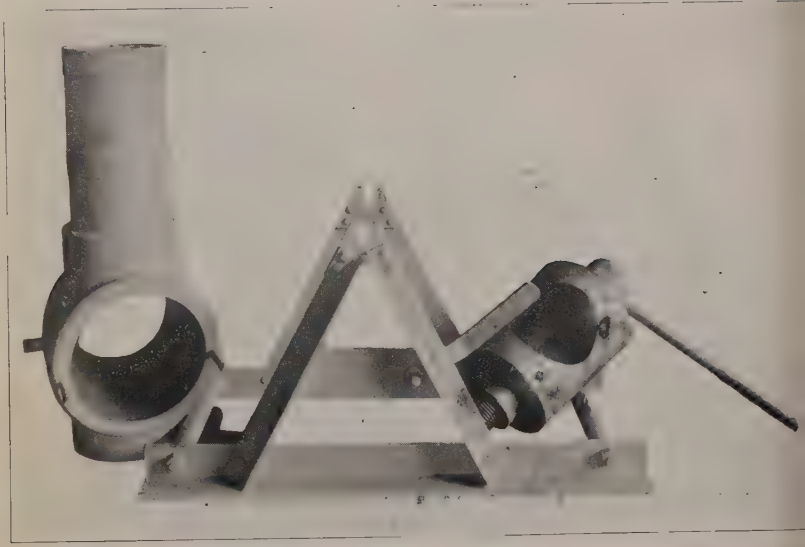

Fig. 3. New Sink and Float Test Apparatus, Dissembled, Showing Construction

The apparatus illustrated accomplishes this purpose. It is shown embled ready for use in Fig. 2. The three separate pieces which ke up the apparatus are shown in Fig. 3, and details of construction the barrel in Fig. 4. The apparatus was made in the laboratory

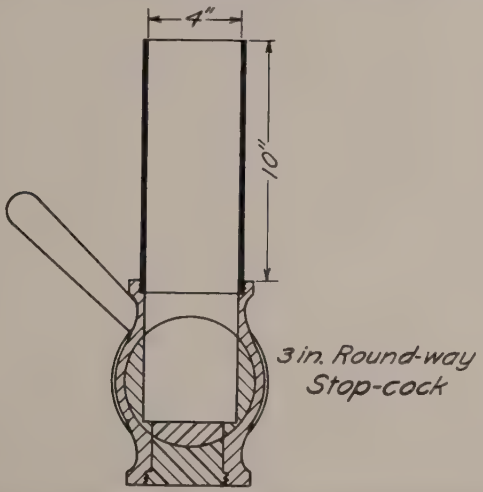

FIG. 4. DETAILS OF BARREL OF NEW SINK AND FLOAT TEST APPARATUS

, of a 3-in. round-way stop-cock valve, a piece of 4-in. galvanized , and a tilting frame. It is so simple in construction and operation very little description is necessary.

The bore of the valve plug was cut out to 4-in. size at one and almost through to the other side of the plug. A cylindrical len core was then inserted, and babbit was poured in around this l up the corners in the interior of the plug and stop up the small of the bore so that the valve plug, instead of a 3-in. round hole gh it, has a 4-in. cylindrical well in it, as shown in Fig. 3. In alve body one opening was cut out to 4 in. in diameter and a gal- ed pipe 10 in. long and 4 in. in inside diameter was soldered on; pposite opening was closed with babbit. The 4-in. galvanized pipe he 4-in. well in the valve plug form the container for the sink and bath. For convenience in manipulation this barrel was pivoted on ing frame fitted with a spring at the bottom for holding the barrel when in the vertical position, and a stop for the valve handle to tate lining up the well in the valve plug with the bore of the nized pipe.

In making a sink and float test the valve handle is turned ove against the stop, forming a continuous cylinder of the pipe and valv which is filled to within about 2 in. of the top with a solution o the desired specific gravity. The coal sample is then immersed in th solution and stirred till thoroughly wetted. It is then allowed t stand undisturbed for a short time to permit the heavy particles t sink to the bottom and the light particles to rise to the top. The valv handle is then turned through 180 degrees, care being used to avoi jerking or jarring the apparatus. This separates the heavy particle in the well of the valve plug from the light particles floating in th upper part of the galvanized cylinder.

By tilting the barrel the float coal and solution is then poure out into a fine screen or a filter, the solution is drained off for use i another determination, and the adhering particles of float coal in th apparatus are flushed out on the filter with a small stream of wate The valve is then turned back to the open position, and the sink coa and solution is poured upon another screen or filter in the sam manner. The products are then washed with water on the screens o filters to remove all trace of the solution used. By using this apparatu with filters for washing the products all the sample is recovered an there is no loss of fines by suspension in the solution. The sma volume of solution used makes the operation with vacuum filters fairl short. On samples from which the slime has been removed a 100-mes screen is used instead of the filter. This apparatus was designed t make the separation just above the top of the sink in the cylinder s that practically all of the solution carrying particles in suspension goe with the float. The float, therefore, includes particles of the sam density as the solution and lighter.

Samples as large as 200 gms. are handled in one operation b an apparatus of the size described. If it is desired to use large samples they should be treated in 200-gm. portions.

For the determination of fine disseminated pyrite, mixtures o chloroform and alcohol and solutions of zinc chloride in water wer used. Chloroform and mixtures of chloroform and alcohol are mor suitable for sink and float tests on fine coal because they are not s viscous as is a zinc chloride solution of equal density. Howeve evaporation losses when using chloroform make the method more e pensive than when a zinc chloride solution is used.

IV. Data and Discussion

13. *Distribution of Forms of Sulphur in the Coal Bed.*—The a on the distribution of the total sulphur, organic sulphur, total itic sulphur, and fine disseminated sulphur content through the tical section of the bed at various places in the three mines exam- l are shown graphically by means of charts, Figs. 6, 7, 11, and 13. exact figures for the percentage of each form of sulphur in each ch at each place where a sample was taken are given in tabular n, with a description of the visible impurities in each bench, in endix I.

In the charts, distance from the roof or top of the coal is laid on the ordinate axis and the percentages of total, pyritic, and nic sulphur are laid off as abscissæ. The dash line represents l sulphur, the unbroken line pyritic sulphur, the dot-dash line nic sulphur, and the dotted line fine disseminated pyritic sulphur. straight vertical lines showing per cent sulphur represent the age values for the forms of sulphur in benches whose relative knesses are represented by the lengths of the lines. The hori- al offsets in these vertical lines are due to variations in the values the forms of sulphur occurring in adjacent benches, and do not n that the sulphur content changes abruptly at these points. The hur percentages plotted in the graphs represent values for ture-free coal.

Middlefork Mine

The No. 6 coal at the Middlefork mine near Benton, Illinois, ages about 7 ft. in thickness, though it varies from 6½ to 8 ft. It shows everywhere the characteristic shale blue l of the No. 6 coal, from 9 in. to a foot and a half above the . In some places in this mine the blue band is pyrite or impregnated with pyrite grains. A sample of the blue band zed 6.39 per cent sulphur and 84.4 per cent ash. The seam divides naturally into three benches, the lower bench separated the middle bench by the blue band and the upper bench or top usually separated from the middle part of the bed by a very parting of charcoal or mother-coal, or simply by a well defined

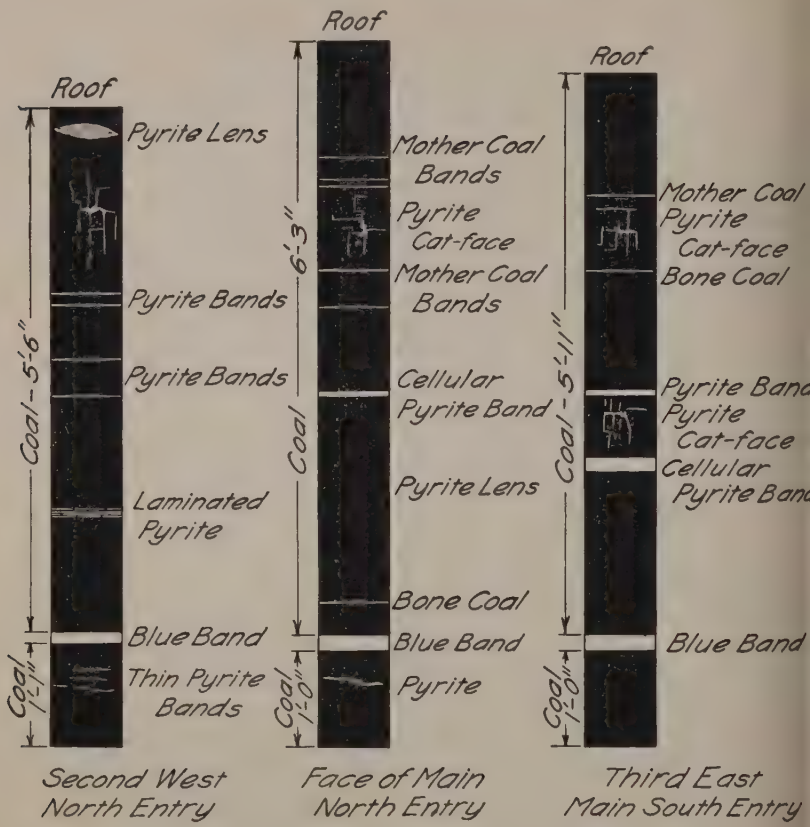

FIG. 5. SECTIONS OF ILLINOIS NO. 6 BED

bedding plane from 12 to 18 in. below the roof. Typical sections of the No. 6 bed showing the occurrence of coarse pyrite infiltrations and other visible impurities at three locations where samples were taken are given in Fig. 6. The moisture content of the coal from this mine averaged 6.45 per cent.

The pyrite occurs chiefly in the form of cat-faces, small flakes or plates and joint fissures, and thin bands less than ¼ in. in thickness. Some thicker bands and lenses of solid pyrite also are found, but a large proportion is in the form of very thin bands, veinlets, or plates of a cellular or friable structure, so that it is very difficult to separate from the coal by hand-picking, and it slimes badly when crushed for washing.

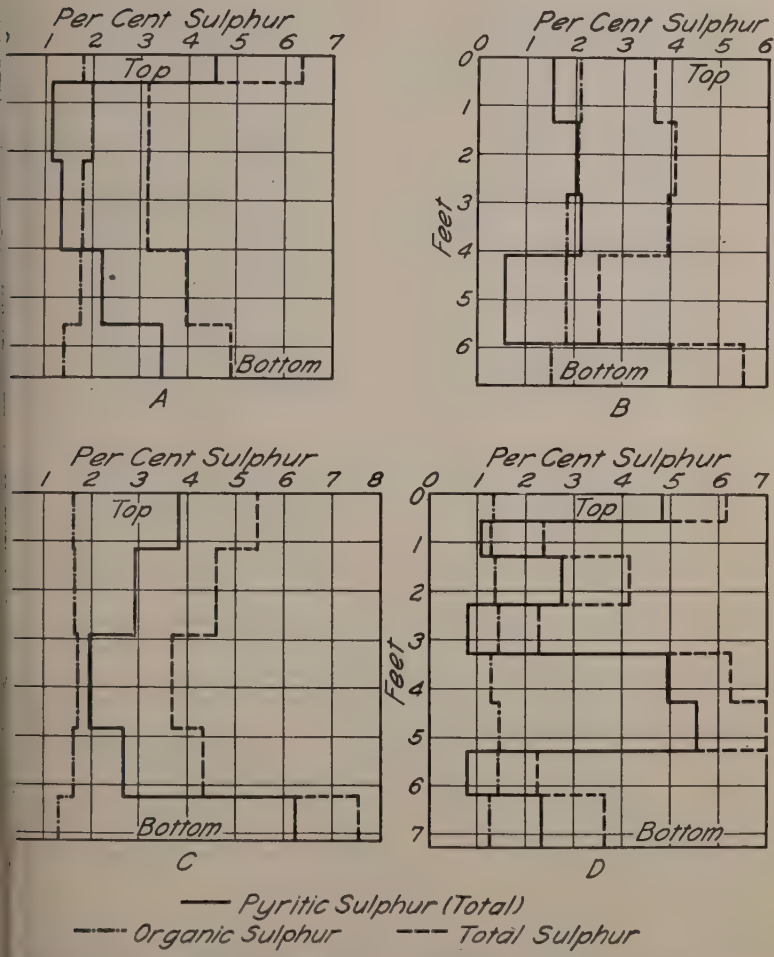

FIG. 6. DISTRIBUTION OF FORMS OF SULPHUR IN THE COAL BED, MIDDLEFORK MINE

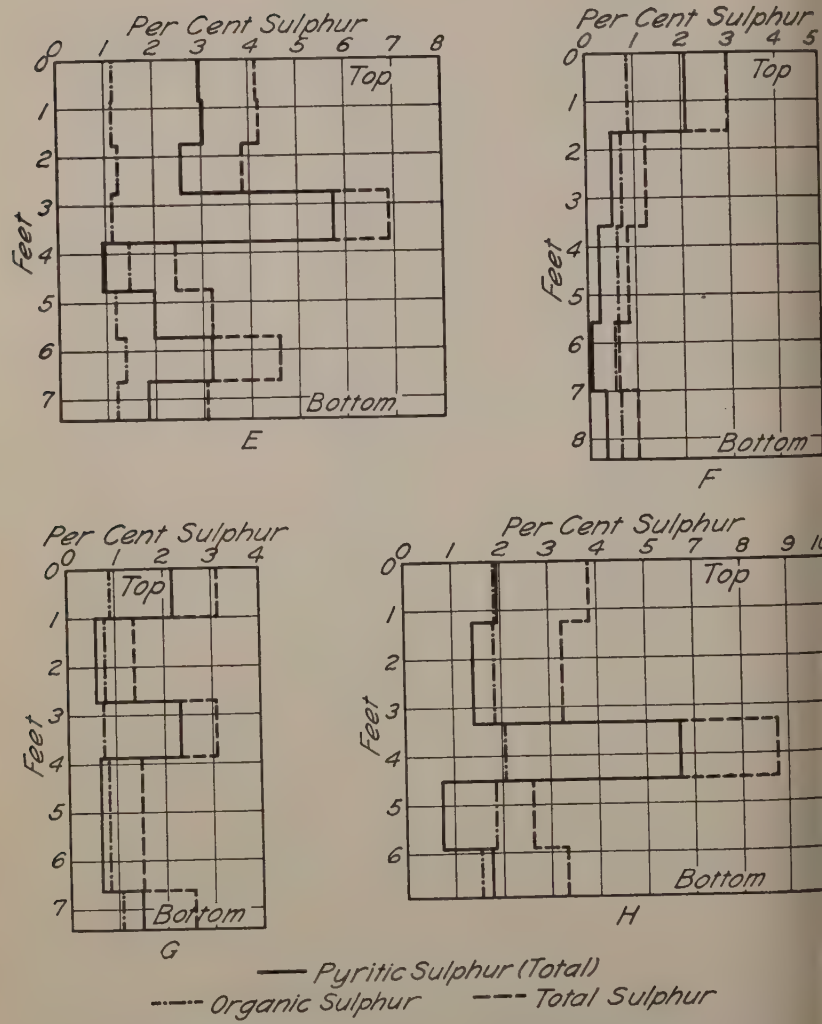

FIG. 7. DISTRIBUTION OF FORMS OF SULPHUR IN THE COAL BED, MIDDLEFORK MINE

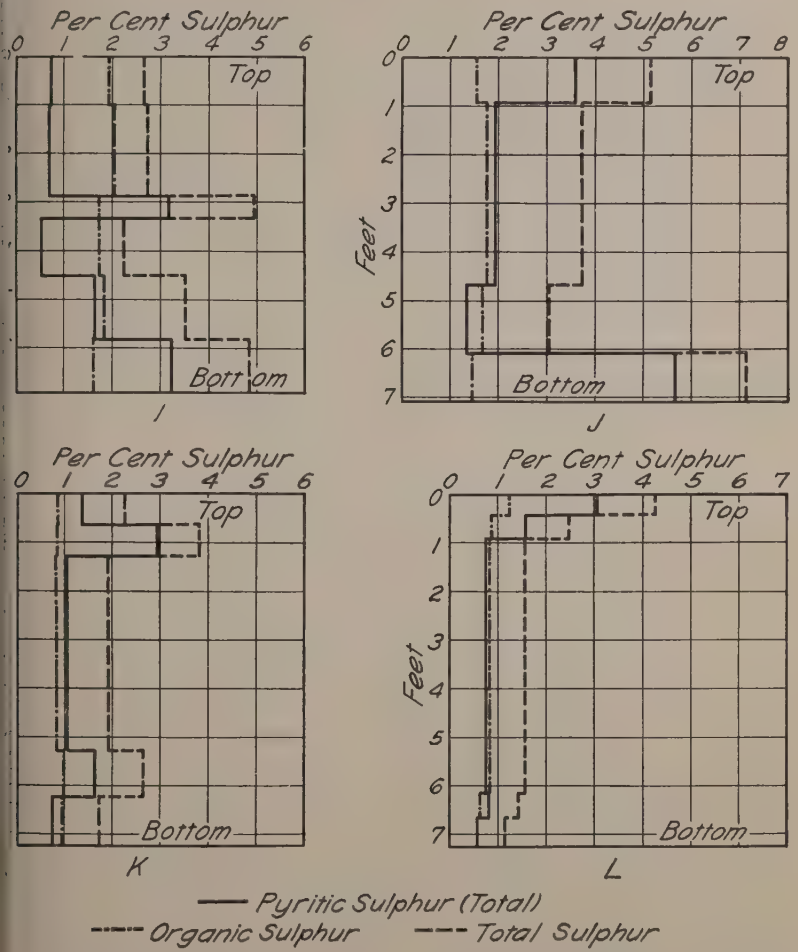

FIG. 8. DISTRIBUTION OF FORMS OF SULPHUR IN THE COAL BED, MIDDLEFORK MINE

The distribution of the forms of sulphur occurring in this mine are plotted in Fig. 6; A, B, C, D, E, and F, and Fig. 7; G, H, I, J, K, and L. Each lettered chart represents a vertical section of the coal bed at one of the places sampled. A small development map of the mine, Fig. 9, shows by corresponding letters the location at which each

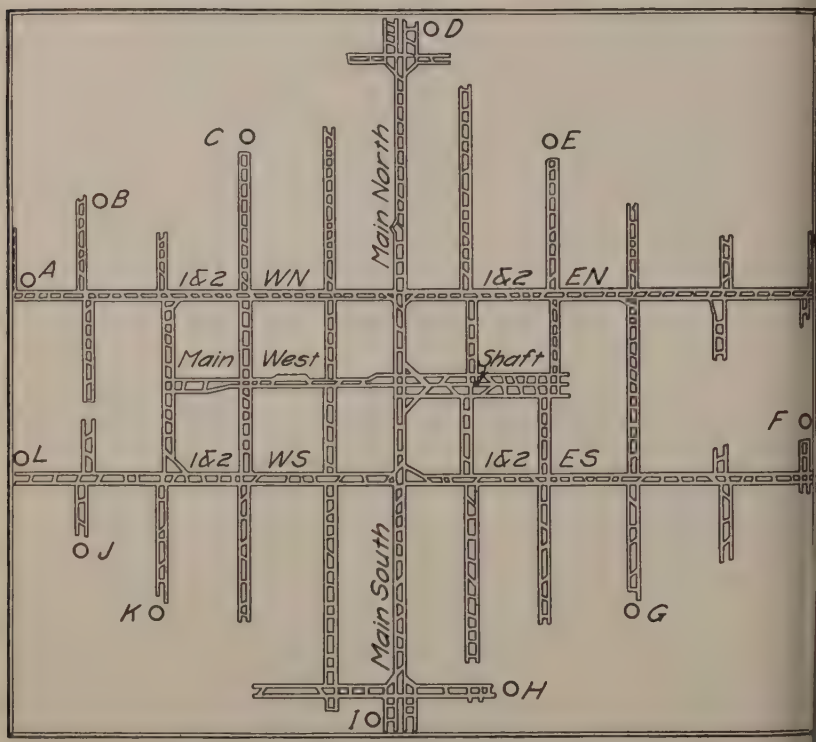

Fig. 9. Skeleton Map of Middlefork Mine

set of samples was taken. The same letters are also used to designat the tables in Appendix I which give the analyses of samples taken a these locations.

It is hardly necessary to point out the great variations in pyriti sulphur content in the vertical span of the seam. This is shown mos clearly in the graphs. In practically every section the total sulphu and the pyritic sulphur are much higher in the top coal and in th coal below the blue band than in the middle benches of the bed. Th

verage total sulphur content of all the top coal samples was 4.17 er cent; of the bottom coal, 3.83 per cent; and the average content the middle benches between the top coal and the blue band was 05 per cent.

The organic sulphur content is shown in the graphs by the dot- ish line. While this does not run uniform from top to bottom of the am the variations are not large. As compared with the very great anges in percentage of pyritic sulphur, the organic sulphur is uite uniform. The greatest divergence in any one section is from a inimum of 0.57 per cent to a maximum of 1.25 per cent. Consider- g the mine as a whole, however, it cannot be said that the organic lphur is constant and uniformly distributed, as the samples varied om this low percentage, 0.57, to as high as 2.10, thus showing the max- um variation over the mine of one and a half per cent. The theory s been advanced that the organic sulphur content of a given bed of al may be constant over large areas and characteristic of that par- ular bed. The results of these investigations, however, would in- ate that the uniformity of organic sulphur distribution is confined very limited areas in the bed and that even for a single mine as whole the variations in organic sulphur content may be considerable.

The average percentages of the different forms of sulphur in the ee natural benches of the coal are given in Table 2. It is to be ed that the coal below the blue band is somewhat lower in organic phur content than either the top or middle coal.

It will be observed from the graphs that, though in general the top l and bottom coal benches are much higher in total sulphur than middle part of the bed, the pyritic sulphur and consequently the al sulphur locally is very erratic in occurrence, and, at some places mpled, sections of considerable thickness near the middle of the face very high in sulphur. This is only partly explainable as due to nce inclusion, in a comparatively small section, of a large lens or d of pyrite. As a comparison of the graphs with the notes in pendix I will show, some benches that showed no conspicuous centrations of visible pyrite analyzed high in pyritic sulphur.

The two samples of mother-coal taken at this mine were much ier than the average coal in pyritic sulphur and ash but very low in anic sulphur. These are samples of mother-coal partings about in. thick, occurring near the roof. One was taken near the face he first East South Entry near F on the map and the other at the of the first West South Entry near L.

TABLE 2

SULPHUR FORMS IN TOP, MIDDLE, AND BOTTOM BENCHES OF NO. 6 COAL IN MIDDLEFORK MINE

Values given in table in per cent, on a moisture-free basis

LOCATION	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash
North side of mine:				
Average top coal samples	5.16	3.55	1.61	10.3
Average middle benches	3.81	2.20	1.61	12.1
Average below blue band	4.96	3.50	1.36	13.8
South side of mine:				
Average top coal samples	3.47	2.14	1.33	8.2
Average middle benches	2.48	1.23	1.25	9.7.
Average below blue band	3.04	1.95	1.09	11.3
Mine average:				
Top coal samples	4.17	2.72	1.45	9.1
Middle benches	3.05	1.65	1.40	10.7
Below blue band	3.83	2.63	1.20	12.3

TABLE 3

FORMS OF SULPHUR IN MOTHER-COAL SAMPLES

Values given in table in per cent, on a moisture-free basis

ample No.	Location	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash
56	1st E. S.	6.63	6.62	0.01	39.3
57	1st W. S.	20.85	20.48	0.37	32.3

Although the samples were very high in pyritic sulphur it was t apparent to the eye, and Sample No. 57 carrying 20.48 per cent ritic sulphur was not conspicuously higher in visible pyrite than mple No. 56 with only 6.62 per cent pyritic sulphur.

There has been considerable speculation as to the composition and gin of mother-coal layers in coal beds. Other investigators who esent analyses of this substance, have generally concluded that ther-coal, while different in composition from the adjacent coal in same bed, is a good grade of fuel not appreciably higher in ash d sulphur content. E. A. Holbrook* gives the analysis of a sample en from a ½-in. band of mother-coal in the No. 6 bed in lliamson County as follows: "Volatile matter, 9.75 per cent; ed carbon, 87.47 per cent; ash, 1.72 per cent; and sulphur, 0.90 cent. This indicates that mother-coal is a high grade coal of ferent composition than the rest of the seam." T. E. Savage† in cussing the vegetable matter of Illinois coal beds says that the neral charcoal generally contains but little, if any, more ash than average coal of the bed in which it occurs. Analysis of a sample mother-coal and of a sample of ordinary coal, both from the No. 6 l in Williamson County, are given as follows:

	Volatile Matter	Fixed Carbon	Ash
Coal	34.91	52.03	10.72
Mother-Coal	23.96	64.28	10.18

the other hand the samples of mother-coal taken at the Middlefork ne in connection with the present work contained much larger centages of both ash and pyritic sulphur than the average coal he bed. In view of these divergent results it is impossible to make generalizations. Additional information on the composition of

* Univ. of Ill. Eng. Exp. Sta., Bul. 88, 62, 1916.

† Journal of Geology 22, 76, 1914.

mother-coal is desirable. The most striking characteristic of the tw samples examined is that they contained practically no organi sulphur.

West Kentucky Coal Co., Mines Nos. 7 and 8

The No. 12 or Caney Fork seam in Kentucky, sampled at the No. mine of the West Kentucky Coal Company, is a high grade low sulphu coal used to a considerable extent as producer gas and by-produc coal. This seam varies from 7 to 9 ft. in thickness and carrie in most places a characteristic shaly bench, consisting of parallel band of shale interbedded with coal and bone-coal, one third the heigh of the coal above the floor and varying from 6 to 12 in. in thickness From 6 in. to 2 ft. of top coal is left up in the room to protect th roof. The moisture content of the coal from this mine averaged 6.2 per cent.

The visible pyrite occurs mainly as thin bands from the thickne of paper up to ¼ in. with only occasional lenses and cat-face Sections at three places sampled showing occurrence of visible im purities are given in Fig. 10. The lenses and cat-faces can be picke out to a certain extent, but the larger part of what pyrite occurs i this mine is too fine for hand-picking.

The No. 9 coal sampled at Mine No. 8 has been correlated with th No. 5 bed mined in Saline County, Illinois. It has, at the No. 8 min where sampled, a thickness of about 5 ft. It is higher in bot sulphur and ash than the No. 12 coal and is sold only for steam an domestic fuel. Visible pyrite occurs mainly in the form of interbedde sheets or bands, varying in thickness up to 1½ in. Those which ar as much as ½ in. in thickness generally hold together well enough t be largely removed by hand-picking. A large proportion of the su phur that is concentrated in definite bands could probably b eliminated by washing.

The data on distribution of sulphur in these beds, secured b analysis of the sectional samples taken, are presented graphically i Fig. 11, N, O, P, Q, R, and S; and Fig. 13, U and V. The location represented by Fig. 11; N, O, P, Q, R, and S, referring to the No. mine, are shown by corresponding letters on the development map Fig. 12.

The great variations in pyritic sulphur content in the vertica span of the seam are shown most clearly in the graphs, where the un

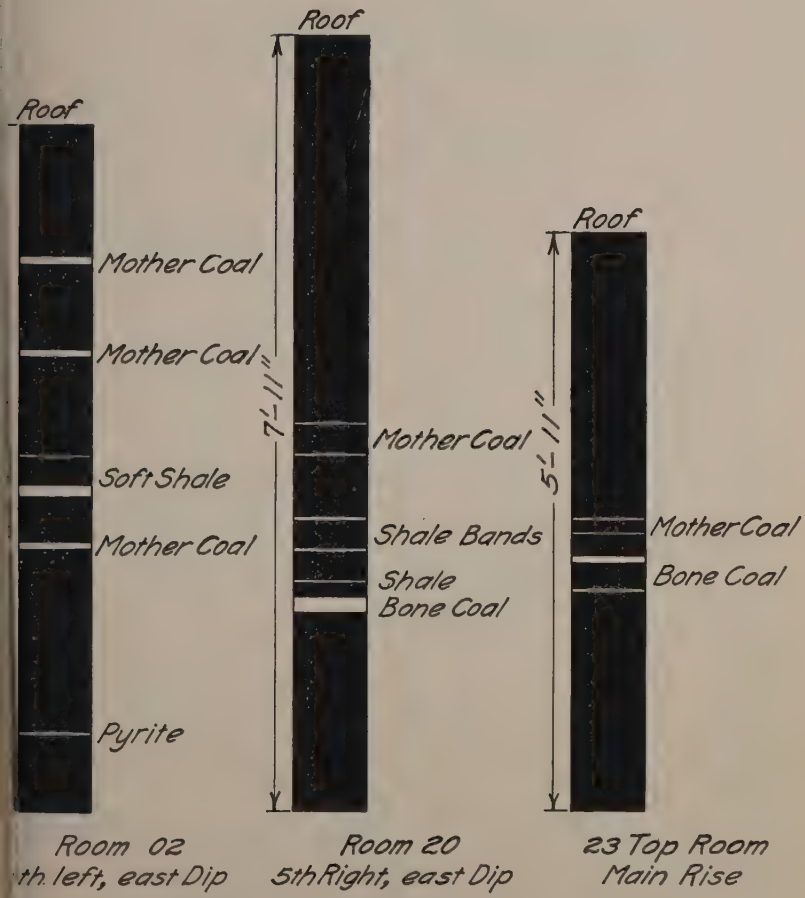

FIG. 10. SECTIONS OF KENTUCKY NO. 12 BED

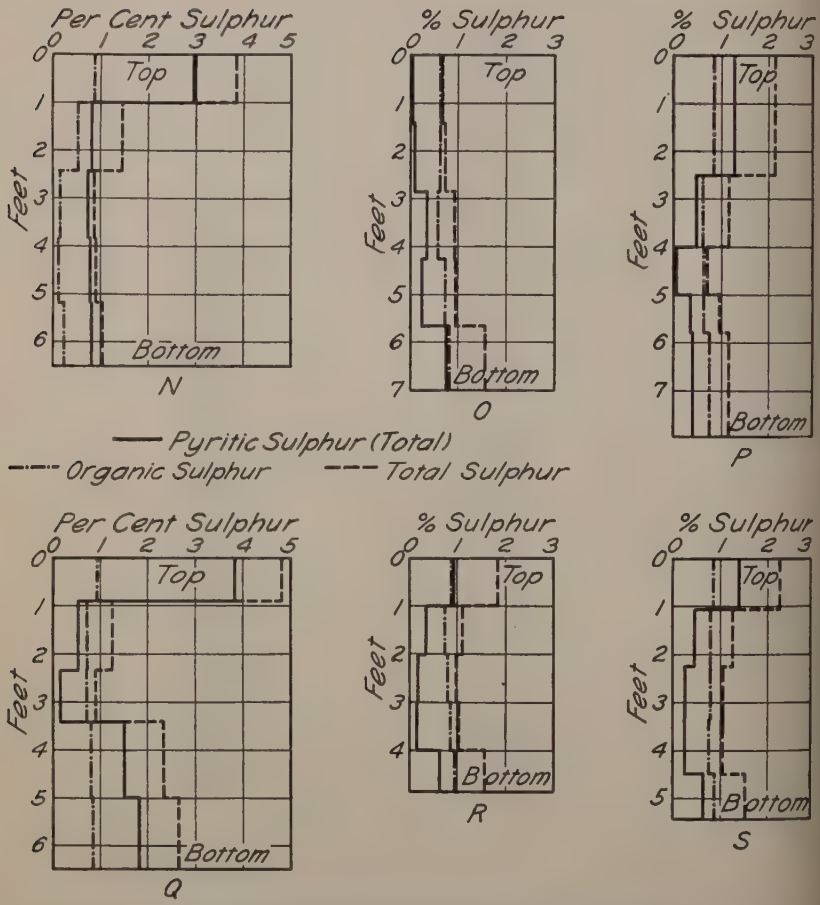

FIG. 11. DISTRIBUTION OF FORMS OF SULPHUR IN COAL BED, MINE NO. 7, WEST KENTUCKY COAL CO.

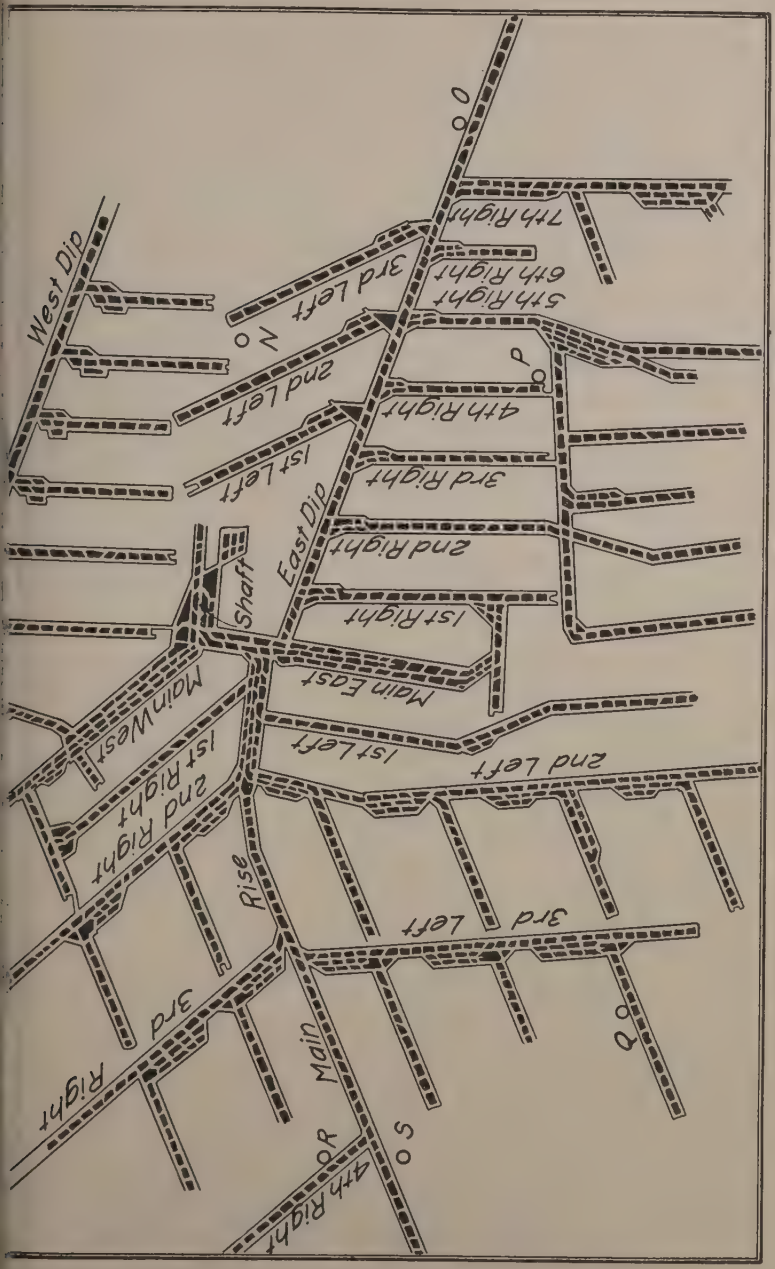

FIG. 12. SKELETON MAP OF MINE NO. 7, WEST KENTUCKY COAL CO.

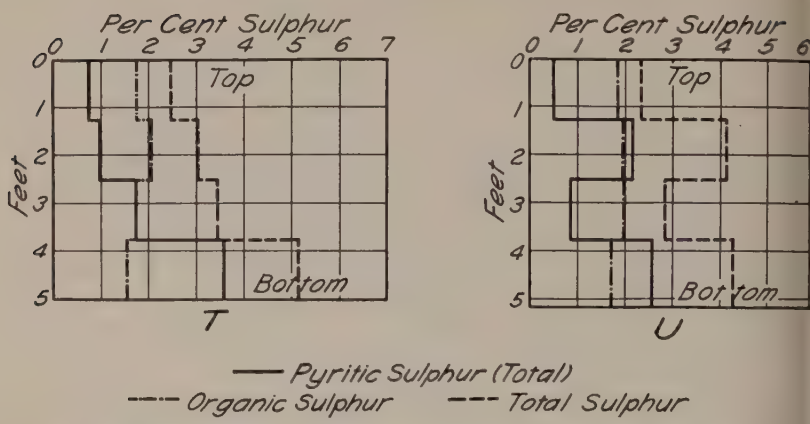

FIG. 13. DISTRIBUTION OF FORMS OF SULPHUR IN COAL BED, MINE NO 8, WEST KENTUCKY COAL CO.

broken line represents the pyritic sulphur content. At almost every place sampled in the No. 7 mine, the total sulphur and the pyritic sulphur content are considerably lower in the middle part of the bed than in the top and bottom coal. At each place the bed was divided into five approximately equal benches for sampling, and as a rule the middle bench was lowest in sulphur, the two adjacent above and below were higher, and the top coal and bottom coal were highest. At the two places where samples of the roof coal were taken, it proved to be higher in sulphur than any other part of the bed in the same location.

The average sulphur content of the different benches of the seam throughout the mine are given in Table 4. Considering only that part of the seam which is mined, the upper section of an average thickness of 1 ft. 3 in. has an average sulphur content of 1.85 per cent. The bottom coal to an average height of 1 ft. 3 in. above the floor averages 1.58 per cent sulphur, and the intervening middle part of the bed averaging about three and a half feet has an average sulphur content of 1.09 per cent. The weighted average of all the samples taken in the mine is 1.48 per cent sulphur and 9.12 per cent ash.

Two sets of sectional samples taken in the No. 8 mine indicate that in this seam the highest total sulphur and pyritic sulphur content are in the bottom coal and that the sulphur content decreases more or less uniformly from the floor to the roof.

AVERAGE OF SULPHUR FORMS IN BENCHES OF No. 12 KENTUCKY BED
West Kentucky Coal Co. Mine No. 7

Values given in table in per cent, on a moisture-free basis

Sample	Average Thickness Ft.	In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float on 1.40	Organic Sulphur	Ash
				Total	Fine			
Top Coal Samples	1	0	3.46	2.57	0.74	1.69	0.91	16.55
	1	3	1.85	1.04	0.28	1.03	0.77	7.32
	1	2	1.03	0.31	0.21	0.96	0.73	8.23
	1	2	0.97	0.26	0.23	1.09	0.72	14.63
	1	4	1.24	0.45	0.23	1.00	0.79	7.36
Bottom Coal Samples	1	3	1.58	0.74	0.32	1.21	0.84	8.76
Average			1.48	0.70	0.34	1.17	0.78	9.12

TABLE 5

AVERAGE OF SULPHUR FORMS IN BENCHES OF No. 9 KENTUCKY BED
West Kentucky Coal Co. Mine No. 8

Values given in table in per cent, on a moisture-free basis

Sample	Average Thickness Ft.	In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float on 1.40	Organic Sulphur	Ash
				Total	Fine			
Top Coal Samples	1	3	2.39	0.61	0.33	2.18	1.79	10.25
	1	3	3.56	1.56	0.56	2.59	2.00	7.46
	1	3	3.14	1.29	0.70	2.79	1.85	9.90
Bottom Coal Samples	1	4	4.70	3.08	1.29	3.17	1.63	14.49
Average			3.46	1.65	0.73	2.69	1.81	10.61

The organic sulphur content is shown in the graphs by the dot-dash line. While this does not run uniform from top to bottom of the seam the variations, as shown in the graphs, are not large. As in the Illinois bed No. 6 coal, the organic sulphur content is quite uniform. As compared with the very great changes in the percentage of pyritic sulphur, the greatest divergence in any one section in the No. 7 mine is from a minimum of 0.72 per cent to a maximum of 0.97 per cent. A closer approach to uniformity of the values for organic sulphur in the different benches at a given location is not obtained by calculating organic sulphur content on a moisture, ash, and pyritic sulphur free basis. The fine disseminated pyrite like the organic sulphur is much more uniform and constant in amount throughout the height or thickness of the bed than is the total pyritic sulphur. These two forms, the organic and the fine disseminated pyritic sulphur, may be regarded as very largely fixed or irremovable sulphur, the percentage of which is more or less constant and characteristic of the bed. The irregularities in the distribution of the total sulphur are due mainly to the concentration of pyrite in bands or lenses which are largely removable by hand-picking or to a greater extent by washing.

Mine No. 7 in the Caney Fork, or No. 12 seam, was sampled on June 17, 1918, by W. B. Plank of the United States Bureau of Mines to determine the suitability of this coal for bunker coal. At that time four channel face samples were taken and designated as follows: Sample G taken at the face of the tenth room, off second south entry, off the seventh right east dip entry, 3000 ft. east of the shaft; Sample H taken at the face of the twenty-fourth room, off third left, off the east dip entry, 1400 ft. northeast of the shaft; Sample I taken at the face of the eleventh room, off the fourteenth south entry, off the second

TABLE 6

ANALYSES OF KENTUCKY BED NO. 12 COAL FROM MINE NO. 7

Values given in table in per cent, on a moisture-free basis

Sample	Moisture	Volatile	Fixed Carbon	Ash	Sulphur	B. t. u.
G	4.49	35.32	49.97	10.22	1.04	12 540
H	4.61	36.55	51.67	7.17	1.08	13 010
I	6.78	33.43	46.39	13.40	1.21	11 710
J	5.99	33.06	52.35	6.60	1.08	12 900
Average	5.47	34.59	50.09	9.35	1.10	12 540

ft main rise, 5100 ft. southeast of the shaft; and Sample J taken t the face of the third south entry, off the third left entry, off the ain rise, 2800 ft. south of the shaft. Analyses of these samples are iven in Table 6.

14. *Relation of Pyritic and Organic Sulphur.*—It is apparent rom the graphs showing the distribution of the sulphur forms that n the beds examined organic sulphur is not concentrated around or ssociated with segregations of iron pyrite, as the curves for organic nd pyritic sulphur show no similarity. A high pyrite content is not ccompanied by high organic sulphur content. On the contrary, in ne majority of cases, in going from one bench or section of the bed the next one adjacent above or below, an increase in pyritic sulphur accompanied by a decrease in organic sulphur and vice versa. This true almost without exception in the north half of the Middlefork ine, where the samples secured averaged much higher in sulphur an in the south side of the mine. This can hardly be interpreted as pporting the idea that organic sulphur contributes to the formation pyritic sulphur, however, as this tendency is not nearly so evident the south side of this mine nor in the other two mines examined.

These graphs show how important is the element of organic sulphur coal and what large proportion of the total sulphur of these coals makes up. Of the thirty samples collected in the West Kentucky o. 7 mine, in only seven does the pyritic sulphur content exceed the ganic sulphur content. Organic sulphur, which is often considered constituting a negligible percentage of the total sulphur of coal, ceeds the pyritic sulphur in twenty-three samples out of the thirty llected in this mine. In the No. 8 mine of this company, the coal higher in organic than in pyritic sulphur in five of the eight samples llected. Of sixty-six regular bench samples collected in the Middle-rk mine, twenty-one carried more organic than pyritic sulphur.

The total sulphur in the average for the No. 7 mine is distributed tween the pyritic and organic forms as follows:

	Per cent
Pyritic sulphur	47.3
Organic sulphur	52.7
Sulphate sulphur	Trace

For the average of the samples collected in No. 8 mine the proportions are:

	Per cent
Pyritic sulphur	47.7
Organic sulphur	52.3
Sulphate sulphur	Trace

At the Middlefork mine the distribution is as follows:

	Per cent
Pyritic sulphur	60.5
Organic sulphur	39.5
Sulphate sulphur	Trace

The sulphate sulphur content of the coal from each of these mines is less than 0.02 per cent in the freshly mined samples.

The graphs of Figs. 14, 15, 16, and 17 were plotted to show any possible relation that might exist in the occurrence of pyritic and of organic sulphur. The pyritic sulphur values were plotted as abscissæ and per cent organic sulphur as ordinates. Fig. 14, repre-

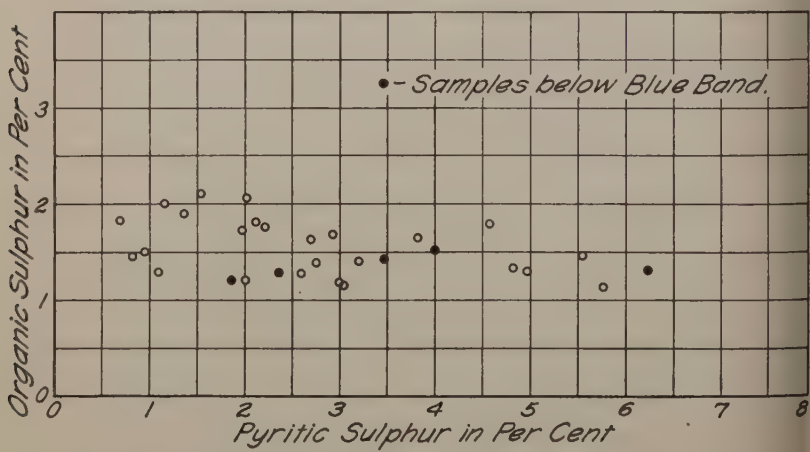

FIG. 14. RELATION OF PYRITIC AND ORGANIC SULPHUR IN THE NORTH HALF OF MIDDLEFORK MINE

senting the samples taken in the north side of the Middlefork mine, shows a general tendency toward lower organic sulphur in the samples high in pyrite. The other graphs, however, show no definite tendency either way in the other half of this mine or in the other two mines

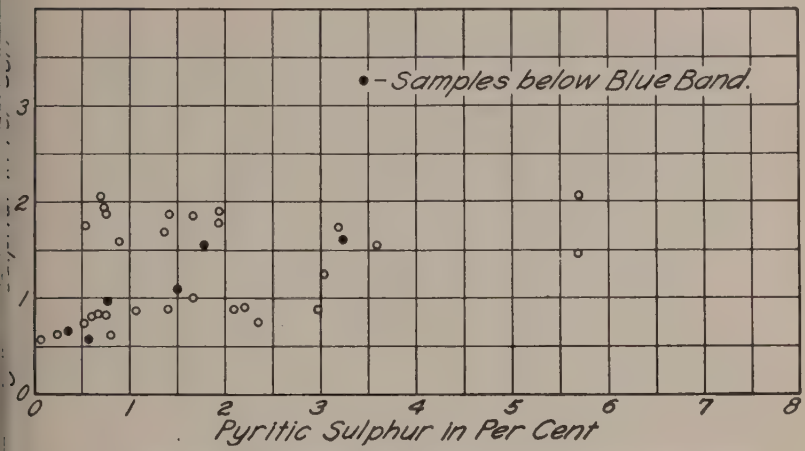

FIG. 15. RELATION OF PYRITIC AND ORGANIC SULPHUR IN THE SOUTH HALF OF MIDDLEFORK MINE

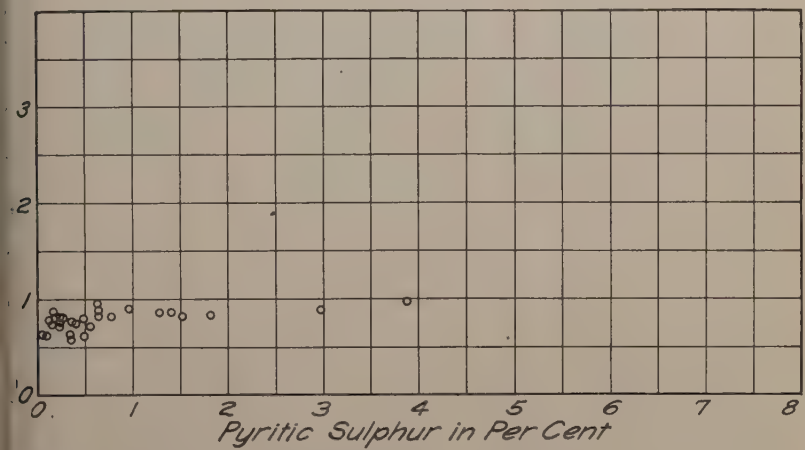

FIG. 16. RELATION OF PYRITIC AND ORGANIC SULPHUR IN MINE NO. 7, WEST KENTUCKY COAL CO.

examined. On the whole the data secured cannot be interpreted as showing any definite relationship between organic sulphur and pyritic sulphur.

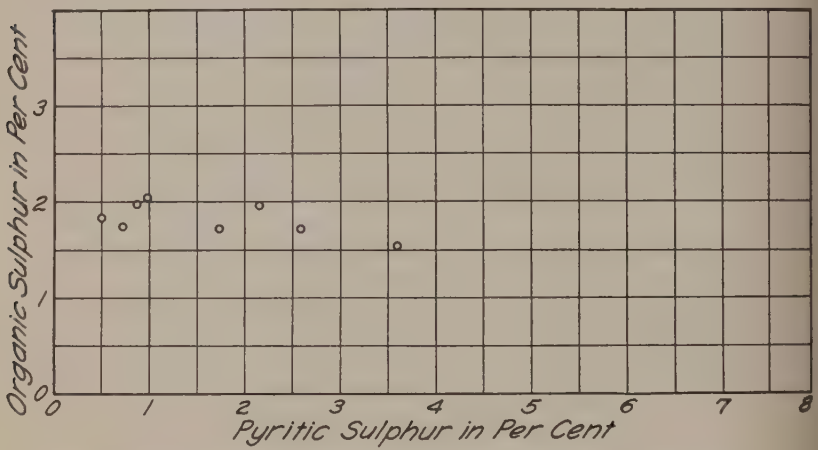

FIG. 17. RELATION OF PYRITIC AND ORGANIC SULPHUR IN MINE NO. 8, WEST KENTUCKY COAL CO.

In order to secure additional data on the possible relation of organic sulphur to pyritic sulphur, a number of special samples were taken of coal immediately surrounding or interbedded with bands or cat-faces of pyrite. These samples were found to be about average or below the average in organic sulphur content. There is no evidence of a concentration of organic sulphur in the coal immediately adjacent to pyrite inclusions. Description and analyses of these samples are given in Table 7.

TABLE 7

SULPHUR FORMS IN SAMPLES HIGH IN PYRITE

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
15	0	7	6.36	4.58	1.78	19.0	Section 7 in. by 1 ft. 9 in. on both sides, and along lens of pyrite. Lens varies from 0 to 1½ in. thick.
15	.....		2.83	0.88	1.95	....	Float on chloroform, 1.48 sp. gr.
20A	0	9	8.70	7.86	0.84	....	Section 9 in. by 1 ft. 9 in. on both sides, and along lens of hard amorphous pyrite and cat-faces of crystalline cellular pyrite.
25A	0	4	8.11	7.63	0.48	....	Section 2 ft. 9 in. along a 1½-in. to 2-in. band of crystalline flaky pyrite.
42	1	0	7.01	5.54	1.47	....	⅝-in. lens of pyrite.
42	.....		2.69	1.19	1.50	....	Float on chloroform, 1.48 sp. gr.
52	1	0	6.90	5.76	1.14	14.0	Vertical vein pyrite ¼ in. by 5 in. and two cat-faces.
56A	.....		7.54	6.28	1.26	....	Strip 6 in. by 2 in. intergrown with veins, bands, and cat-faces of crystalline pyrite.
56A	.....		2.73	1.43	1.30	....	Float on chloroform, 1.48 sp. gr.
63	0	5½	4.93	3.19	1.74	11.7	5½ in. by 2 ft. 5 in. along high sulphur.
68	1	2	7.76	5.70	2.06	16.5	¾-in. band hard pyrite, 1½-in. band cellular pyrite, and small cat-face.
71	0	6	6.47	4.98	1.49	20.1	1 in. to 2 in. on each side and between two ½-in. bands of pyrite, 3 ft. from bottom.

15. *Forms of Sulphur in Raw and Washed Coals.*—It is evident that if organic sulphur segregates with or is concentrated around pieces of pyrite, bone-coal, or shale, which are all of higher specific gravity than the coal itself, it will be removed along with these impurities as the refuse in the washing operation. On the other hand, if the occurrence of organic sulphur is independent of the distribution of these impurities, their separation should not greatly affect the amount of organic sulphur found in the washed coal, except as a slight increase due to the removal of non-coal impurities, inorganic in nature and containing no organic sulphur. This increase in the organic sulphur content of the washed coal would of course be dependent upon the amount of inorganic impurities removed, and only in unusual cases would the increase be appreciable.

In order to obtain data on this question and on the forms of sulphur in raw and washed coal, seven samples of run of mine raw coal were obtained at the Middlefork mine, in addition to the face samples collected in the mine. Each raw coal sample represents a day's production for the mine, which varies between 2400 and 2800 tons. A sample of washed coal representing one day's operation of the washery, on an average day, was secured for the purpose of comparing the forms of sulphur present in the raw and the washed coal. Table 8 shows the forms of sulphur present in the raw and the washed coal from the Middlefork mine and washery, together with the average for the face samples collected in the mine.

Table 8 shows the average sulphur values for about 17 500 tons of coal representing seven days' production. The sulphur content varies

TABLE 8

FORMS OF SULPHUR IN RAW AND WASHED COALS FROM THE MIDDLEFORK MINE

Values given in table in per cent, on a moisture-free basis

Sample No.	Total Sulphur	Pyritic Sulphur	Organic Sulphur
72 Raw Coal	3.68	2.42	1.26
73 Raw Coal	3.20	1.90	1.30
74 Raw Coal	3.22	1.99	1.23
75 Raw Coal	3.59	2.07	1.52
76 Raw Coal	3.33	1.93	1.40
77 Raw Coal	3.27	2.08	1.19
78 Raw Coal	2.77	1.55	1.22
Average for raw coal	3.29	1.99	1.30
Average of face samples for mine	3.30	1.94	1.38
Washed coal	2.25	0.92	1.33
Refuse	13.45	....	....

rom day to day, but the monthly average for total sulphur is about 3.25 per cent. The average of samples 72 and 78 inclusive, here shown as 3.29 per cent sulphur, therefore represents closely the average production of the mine for total sulphur. Attention is directed to the comparison of the average values for the different forms of sulphur in the run of mine coal with the average for the sectional face samples collected in the mine. For total sulphur the values are 3.29 and 3.30 per cent, for pyritic sulphur 1.99 and 1.94 per cent, and for organic sulphur 1.30 and 1.38 per cent, respectively. This indicates that the sectional face samples collected in the mine are, as a whole, representative of the mine production.

It is interesting to note that the values for organic sulphur in the run of mine raw coal, and in the sample washed coal, are nearly identical; namely, 1.30 per cent for the raw coal and 1.33 per cent for the washed coal. These figures are shown in Table 8 given above. Though the washed coal sample does not necessarily represent the product obtained by washing the identical coal of the run of mine samples, these figures must be taken to show that little or no organic sulphur is removed by the washing process.

Similar data* have been secured as to the effect of washing on forms and distribution of sulphur on two other coals. Table 9 shows the results for a coal from White County, Tennessee, and for samples representing a day's run at a 1200 ton commercial washery in Williamson County, Illinois. The five washed coals are the various trade sizes produced at this washery.

TABLE 9

FORMS OF SULPHUR IN RAW AND WASHED COALS

Values given in table in per cent, on a moisture-free basis

Source and Grade of Coal	Total Sulphur	Pyritic Sulphur	Sulphate Sulphur	Organic Sulphur
White County, Tennessee:				
Raw coal	4.87	3.59	0.11	1.17
Table-washed coal	3.02	1.84	less than 0.01	1.18
Jig-washed coal	3.80	2.61	....	1.19
Williamson County, Illinois:				
Raw coal	1.83	1.04	Trace	0.79
No. 1 washed coal	1.81	1.05	....	0.76
No. 2 washed coal	1.56	0.78	....	0.78
No. 3 washed coal	1.57	0.82	....	0.75
No. 4 washed coal	1.57	0.81	....	0.76
No. 5 washed coal	2.33	1.57	....	0.76

* Fraser and Yancey, Am. Inst. Min. Eng., Bul. 153, 1822, 1919.

These results indicate that only pyritic and sulphate sulphu are removed by washing. Iron sulphate resulting from the oxidatio of pyrite is soluble in the wash water. Gypsum occurring in thi plates is difficult to separate with the refuse. From these considera tions it is believed that the sulphate sulphur of the White County Tennessee, raw coal resulted from the oxidation of pyrite, rather tha from the presence of calcium sulphate, since sulphate sulphur i almost entirely absent in the clean washed coal.

An inspection of Tables 8 and 9 indicates that organic sulphu is distributed more or less uniformly through the coal substance an that it is not concentrated with or around the pyrite or shale deposits or other heavy material which is removed by coal dressing processe such as washing. The values for organic sulphur in the washed coa agree quite closely with the organic sulphur content of the corre sponding raw coal. There is no marked evidence of noticeably highe values for this sulphur form in the washed products than in th raw coals, because none of the three coals listed in the tables ra abnormally high in non-coal impurities, the removal of which woul cause an appreciable concentration of organic sulphur in the washe coal. Because of the presence of large amounts of such impuritie in the raw coal, washed coal sometimes contains a higher percentage o total sulphur than the original raw coal.

In estimating the washability of a coal the organic sulphur con tent is an important consideration. The chief value in experimenta coal washing of the determination of this constituent lies in findin a value below which there can be no reduction of sulphur content b mechanical processes of separation. For example, if the coal from given mine averages two per cent total sulphur and one per cen organic sulphur, it would of course be impossible to secure a washe product carrying less than one per cent sulphur. Although this is self evident fact, it is of such importance in determining the wash ability of a coal that attention is directed to it. Furthermore, in al coals a part of the pyritic sulphur will remain in the washed coal the amount depending, as has already been pointed out, upon th physical form in which the pyrite occurs in that particular coal. Thu in every case the minimum sulphur content that may be obtained i the clean coal is well above the organic sulphur content of the raw coal. All the pyrite occurring in the form of microscopic particles and a large part of that included under the classification "fine dis

TABLE 10

PYRITIC AND ORGANIC SULPHUR IN VARIOUS COALS

Values given in table in per cent, on a moisture-free basis

Location of Mine	Coal Bed	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Organic Sulphur as Per Cent of Total Sulphur
*Clearfield Co., Pa.	C & D	3.48	2.77	0.71	20.4
White Co., Tenn.	Sewanee	4.87	3.59	1.17	24.0
Pike Co., Ky.	Freeburn	0.46	0.13	0.33	72.0
Williamson Co., Ill.	No. 6	1.83	1.04	0.79	43.2
Greene Co., Ind.	No. 4	1.66	0.89	0.77	46.4
Franklin Co., Ill.	No. 6	3.29	1.99	1.30	39.5
Webster Co., Ky.	No. 12	1.48	0.70	0.78	52.6
Union Co., Ky.	No. 9	3.46	1.65	1.81	52.5
†McDowell Co., W. Va.	Pocahontas No. 3	0.55	0.08	0.46	83.7
†Letcher Co., Ky.	Elkhorn	0.68	0.13	0.51	75.0

*H. F. Yancey and Thomas Fraser, Coal Industry 3, (1919) 36.

†A. R. Powell, J. Ind. Eng. Chem., 12, (1920) 889.

seminated pyrite," is not removable, and for practical purposes i connection with coal washing may be considered as fixed sulphur.

16. *Organic Sulphur in Various Coals.*—The relatively hig proportion of sulphur occurring in the organic form in many coal has not been generally recognized. Table 10 shows the total, pyritic and organic sulphur values for a number of well known coals rep resenting both Eastern and Central District fields. For each coal th percentage of the total sulphur in organic combination is tabulated It will be noted that the percentage of the total sulphur present a organic sulphur varies from 20.4 per cent in a coal from Clearfiel County, Pennsylvania, to 83.7 per cent in a coal from McDowe County, West Virginia.

17. *Microscopic Pyrite.*—At the Middlefork mine six samples o coal were taken for the examination of the microscopic pyritic sulphu

The thin cross-section and photographs of these samples were mad at the Pittsburgh Station of the Bureau of Mines by Dr. Reinhard Thiessen, Microscopist of the Bureau of Mines, who has made a study o the microscopic forms of sulphur in various Eastern and Central Distric coals.* All of the coals that he examined were found to contain vary ing amounts of sulphur in the form of very small globules or particle of pyrite. "These particles are seen in thin section as roughly rounde opaque dots. When isolated, they are generally shown to be roughl spherical in shape with a rough outer surface. They vary in diamete from a few microns to a hundred microns†, the majority measurin from 25 to 40 microns, relatively few exceed the latter diameter; the are therefore very small objects. . . . The amount of pyrite occurrin in this form varies considerably in different beds from which coal have been examined, and also in different samples from the sam bed, or even in different parts of the same section. A section withou these pyrite particles is rarely obtained. So far, no regularity ha been discovered." Photographs of the thin sections made from th Middlefork coal samples are shown in Figs. 18 to 24. The photograph are all magnified approximately 200 times. The microscopic pyrit is represented by black areas, more or less circular in shape, with

* Am. Inst. Min. Eng., Bul. 153, 2431, 1919.

† A micron is the thousandth part of a millimeter or one twenty-five thousandth of a inch.

Fig. 18. Microphotographs of Samples of Illinois No. 6 Coal, Showing Microscopic Pyrite

FIG. 19. MICROPHOTOGRAPHS OF SAMPLES OF ILLINOIS NO. 6 COAL, SHOWING MICROSCOPIC PYRITE

FIG. 20. MICROPHOTOGRAPHS OF SAMPLES OF ILLINOIS NO. 6 COAL, SHOWING MICROSCOPIC PYRITE

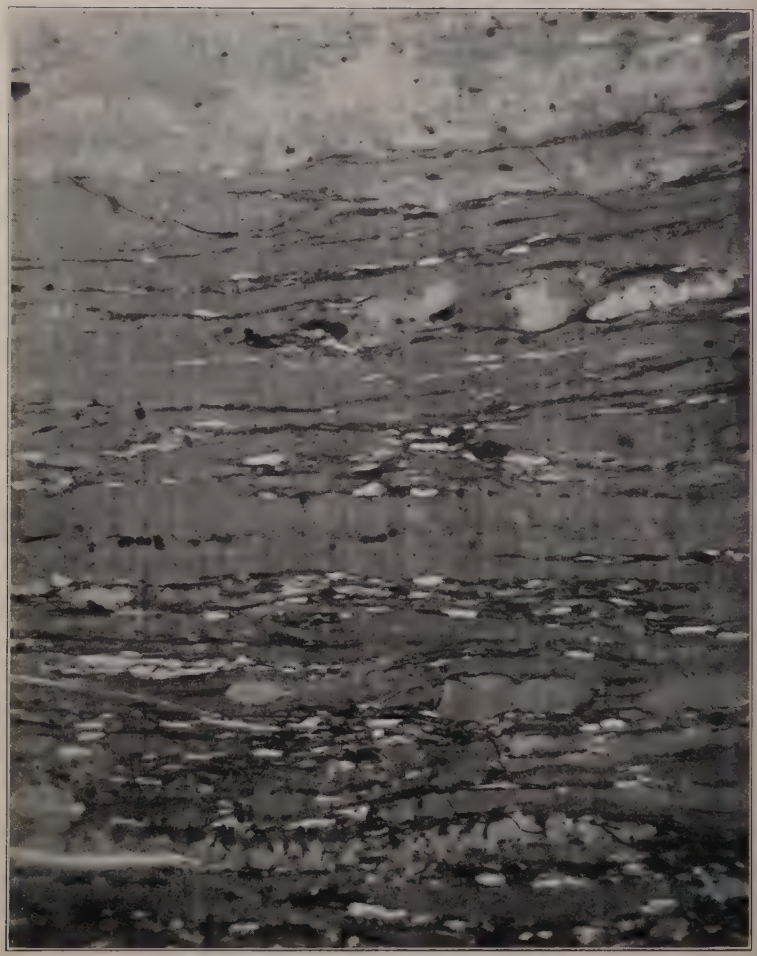

FIG. 21. MICROPHOTOGRAPHS OF SAMPLES OF ILLINOIS NO. 6 COAL, SHOWING MICROSCOPIC PYRITE

FIG. 22. MICROPHOTOGRAPHS OF SAMPLES OF ILLINOIS NO. 6 COAL, SHOWING MICROSCOPIC PYRITE

Fig. 23. Microphotographs of Samples of Illinois No. 6 Coal, Showing Microscopic Pyrite

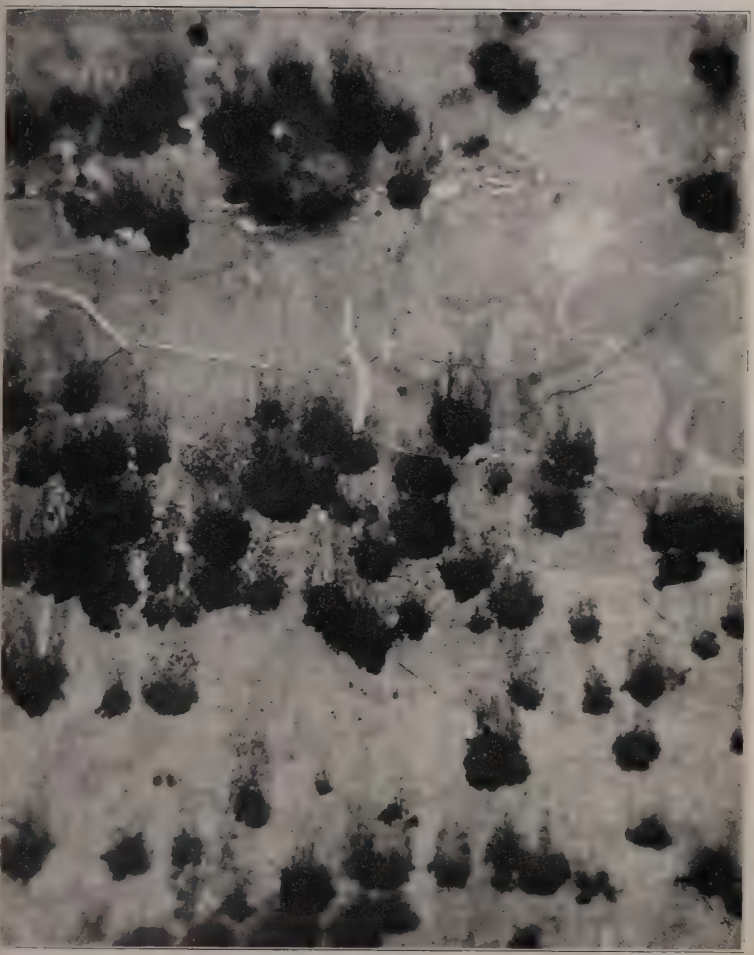

FIG. 24. MICROPHOTOGRAPHS OF SAMPLES OF ILLINOIS NO. 6 COAL, SHOWING MICROSCOPIC PYRITE

reak on one or more sides. The streak was made during the prep-ration of the thin cross-section and, of course, is not originally present the coal. The photographs are cross-sections, that is, they are erpendicular to the bedding.

The pyrite globules vary in diameter from a few microns to out 60 microns. The average diameter is 20 microns. Since the ening in a 100-mesh standard screen is 147 microns it will be seen at a 100-mesh grain of coal might contain a considerable number such globules.

Samples of the top and middle benches of the coal were taken for is work. Five photographs were made of sections of the top coal. wo of these photographs are included here, Figs. 18 and 19. The p coal showed less microscopic pyrite than any of the samples of iddle coal, though in the great majority of cases, it is higher in total id pyritic sulphur than the middle coal. Either the samples of top al were not representative of this condition, or a smaller amount of e pyritic sulphur of the top coal occurs in the microscopic form.

The middle coal shown in Figs. 20 and 21 was taken at the same ation as the top coal. The face at this location was not visibly high sulphur. Cat-faces and bands and veinlets of pyrite were not un-ually numerous. However, samples of middle coal shown in Figs. , 23, and 24 were taken at a location which was visibly somewhat gher in pyrite, and the photographs show this condition with respect microscopic pyrite. The average for this location is represented Fig. 23.

V. Summary of Conclusions

A study of the data given in this bulletin suggests the following summary of conclusions.

18. *Distribution of Pyritic Sulphur.*—Extreme irregularity of distribution is characteristic of the pyritic sulphur of coal in the bed.

1. The irregularities in the distribution of total sulphur are due mainly to the concentration of pyritic sulphur in coarse bands or lenses.

2. Fine disseminated pyrite is much more uniformly distributed than is coarse pyrite.

3. Microscopic pyrite was found in all the samples examined. The amount of pyritic sulphur in this form cannot be accurately determined because it varies widely even in the same thin section.

19. *Distribution of Organic Sulphur.*—As compared with the very great changes in pyritic sulphur content the vertical distribution of organic sulphur at a given location in the same bed is quite uniform. The results of this investigation, however, would indicate that in high sulphur coals the uniformity of organic sulphur distribution is confined to very limited areas in the bed, and that taking even a single mine as a whole the variations in organic sulphur content may be considerable, although it is much more uniformly distributed than is the pyritic sulphur. In low sulphur coals the variations in the distribution of organic sulphur are less and the values obtained for organic sulphur approach uniformity, even for considerable areas.

20. *Relation of Pyritic and Organic Sulphur.*—There is little evidence of a definite relationship in the occurrence of organic and pyritic sulphur. High pyritic sulphur in a bench or section of a bed is not indicative of a correspondingly high organic sulphur content.

The proportion of the total sulphur that is in organic combination in various coals (Table 10) varies within wide limits. In low sulphur coals organic sulphur makes up a greater percentage of the total sulphur content than it does in high sulphur coals.

Organic sulphur makes up a greater proportion of the total sulphur content of coal than is generally recognized. In the 104 face

amples taken in three coal beds, organic sulphur exceeded pyritic in 9 samples.

21. *Practical Applications.*—In estimating the washability of a al the organic sulphur content is an important consideration. The hief value in experimental coal washing of the determination of this onstituent lies in finding a value below which there can be no reduction of sulphur content by mechanical processes of separation, since ne organic sulphur content of coal is not reduced by such methods. urthermore, in all coals a part of the pyritic sulphur will remain n the washed coal, the amount depending upon the physical form in hich the pyrite occurs in that particular coal. Thus in every case ne minimum sulphur content that may be obtained in the clean coal is ell above the organic sulphur content. All of the pyritic sulphur occurring in the form of microscopic pyrite, and a large part of that ncluded under the classification of "fine disseminated pyrite," is not emovable, and for practical purposes in connection with coal washing nay be considered as "fixed" sulphur.

The organic sulphur content of some coals is sufficiently high to mit seriously the extent to which these coals can be cleaned of sulphur y washing.

In some coal beds partial concentration of the pyritic sulphur n the form of thick bands or lenses at certain definite horizons akes it possible to clean the coal by selective mining or hand-picking.

APPENDIX I

Tables Showing Forms of Sulphur in Sectional Samples

United States Fuel Co., Middlefork Mine, Iliinois, No. 6 Bed.—Th following Tables A to L give the figures for total sulphur, organi sulphur, total pyritic sulphur, and fine disseminated pyritic sulphu in the sectional samples taken at the Middlefork mine near Bentor Illinois. These same data have been presented graphically in Fig. 1 Charts A, B, C, D, E, and F, and in Fig. 2, Charts G, H, I, J, K, an L, lettered to correspond with the designation of the tables. The loca tions at which the samples were taken in the mine are shown by corre sponding letters on the map, Fig. 9. Table M gives the weighte average of the forms of sulphur for the bed at the various locations i the Middlefork mine. Below the analyses of each section is given in parentheses, a statement of the visible impurities occurring in th section. These impurities were included in the sample except wher otherwise specified.

Table A

Forms of Sulphur in Sectional Samples

Middlefork Mine—Illinois Bed No. 6

Second West North at Mouth of Tenth North Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
15	0	7	6.36	4.56	0.72	2.67	1.80	19.0	Section 7 in. by 1 ft. 9 in. on both sides and along lens of pyrite. Lens varies from 0 to 1½ in. thick; most of pyrite itself cleaned of coal and discarded; 4 in. of top coal not sampled.
14	1	7.5	3.15	1.15	0.55	2.60	2.00	7.6	Two ⅛-in. pyrite bands, one small cat-face.
13	1	10	3.16	1.36	0.49	2.36	1.80	10.8	One ⅛-in. band and one $\frac{1}{16}$-in. band of pyrite.
12	1	6.5	3.97	2.21	0.62	2.64	1.76	17.9	One ½-in. band laminated pyrite 1 ft. 3 in. up from blue band.
11	1	1	4.90	3.47	1.18	3.03	1.43	15.4	Three knife-edge sulphur bands.
Average	.....		3.88	2.12	0.67	2.62	1.76	13.3	

Note: Location of section shown on mine map at (A); data shown graphically in Fig. 6A. Total thickness of bed, 6 ft. 8 in.

TABLE B

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Room 11, off the Seventh North First West North Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
10	1	4	3.63	1.53	2.10	8.3	¼-in. band pyrite.
9	1	6	4.08	2.02	2.06	8.4	Two ⅛-in. bands pyrite; 1 veinlet ⅛-in. by 2 in.
8	1	3	3.93	2.11	1.82	10.2	Two ⅛-in. pyrite bands; cat-face 4 sq. in.
7	1	10	2.51	0.68	1.83	14.3	Knife-edge veins of pyrite.
6		10.5	5.52	4.00	1.52	15.3	
Average	.....		3.72	1.82	1.90	11.1	

Note: Location of section shown on mine map at (B); data shown graphically in Fig. 6B. Total thickness of bed, 6 ft. 9½ in.

Table C

Forms of Sulphur in Sectional Samples

Middlefork Mine—Illinois Bed No. 6

Face of Fourth North, off First West North Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
5	1	2	5.47	3.82	1.45	3.42	1.65	13.3	⅛-in. pyrite band.
4	1	9	4.60	2.92	1.19	2.99	1.68	9.5	Pyrite cat-face 4 sq. in. and ⅛-in. band pyrite.
3	1	11	3.70	1.97	0.59	2.44	1.73	11.2	Diagonal pyrite veinlet ⅛-in. by 4 in.
2	1	5	4.32	2.69	0.91	2.87	1.63	17.2	Two ¼-in. bands mother-coal.
1		10.5	7.55	6.23	1.26	3.17	1.32	18.0	
Average	.....		4.82	3.17	1.14	2.91	1.65	13.2	

Note: Location of section shown on mine map at (C); data shown graphically in Fig. 6C. Total thickness of bed, 7 ft. 1½ in.

TABLE D

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Face of Main North Back Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
47		7	6.16	4.82	1.34	10 0	
46		8.5	2.39	1.09	1.30	8.3	1/8-in. mother-coal.
45	1	0	4.14	2.75	1.39	8.9	1/4-in. pyrite cat-face, two 1/8-in. bands mother-coal.
44	1	0	2.28	0.82	1.46	6.5	Two 1/2-in. bands mother-coal.
43	1	0	6.26	4.96	1.30	13.8	One 3/4-in. band cellular pyrite.
42	1	0	7.01	5.54	1.47	19.1	5/8-in. lens of pyrite.
41	1	0	2.26	0.81	1.45	13.8	1/2-in. bone-coal.
40	1	0	3.64	2.35	1.29	10.8	1/8-in. pyrite.
Average	.....		4.24	2.88	1.36	11.6	

Note: Location of section shown on mine map at (D); data shown graphically in Fig. 6D. Total thickness of bed, 6 ft. 9 in.

TABLE E

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Thirty Feet Out by Face of Third North, off First East North Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
55		10	4.17	2.98	1.19	10.7	
54		11	4.20	3.04	1.16	10.1	
53	1	0	3.87	2.59	1.28	10.2	Vertical pyrite streak ¼-in. by 3 in.
52	1	0	6.90	5.76	1.14	14.0	Vertical vein pyrite ¼-in. by 5 in.; 2 cat-faces.
51	1	0	2.45	0.95	1.50	8.6	¼-in. mother-coal; small cat-face.
50	1	0	3.20	2.00	1.20	14.8	⅜-in. band pyrite.
49		10.5	4.60	3.20	1.40	13.6	½-in. hard pyrite.
48		9.5	3.09	1.87	1.22	9.7	
Average	.....		4.08	2.95	1.27	11.5	

Note: Location of section shown on the mine map at (E); data shown graphically in Fig. 7E. Total thickness of bed, 7 ft. 3 in. Top coal not included.

TABLE F

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Face of Tenth North, off First East South Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
20	1	8	2.98	2.09	0.89	9.0	
19	1	11	1.25	0.52	0.73	7.0	One ¼-in. band black shale.
18	2	0	0.85	0.24	0.61	7.9	Two ⅛-in. bands and one ¼-in. band of mother-coal.
17	1	5	0.62	0.06	0.56	10.1	
16	1	5	1.00	0.35	0.65	7.9	
Average	.....		1.35	0.66	0.69	8.3	

Note: Location of section shown on the mine map at (F); data shown graphically in Fig. 7F. Total thickness of bed, 8 ft. 2 in.

TABLE G

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Fifth South, off First East South Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
25	1	0	3.13	2.2	0.84	1.81	0.91	7.7	Three vertical veinlets of pyrite.
24	1	8.5	1.40	0.60	0.59	1.44	0.80	8.0	One ¼-in. shale band.
23	1	2	3.09	2.34	0.70	1.50	0.75	6.5	One small cat-face.
22	2	9	1.51	0.67	0.48	1.41	0.84	11.1	One ½-in. band and one ¾-in. band of mother-coal.
21		9.5	2.59	1.50	0.75	1.95	1.09	10.5	
Average	.....		2.07	1.22	0.62	1.54	0.85	9.2	

Note: Location of section shown on mine map at (G); data shown graphically in Fig. 7G. Total thickness of bed, 7 ft. 5 in.

TABLE H

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Last Crosscut Between Third and Fourth East, off Main South Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
70	1	3	3.84	1.94	1.90	8.2	
69	2	1	3.28	1.41	1.87	9.5	½-in. mother-coal; ⅛-in. bone-coal; small cat-face; ¼-in. mother-coal.
68	1	2	7.76	5.70	2.06	16.5	¾-in. band hard pyrite; 1½-in. cellular pyrite; one cat-face.
67	1	5	2.62	0.75	1.87	12.3	
66	1	0	3.33	1.78	1.55	12.0	Blue band pyritized.
Average	.....		4.01	2.15	1.86	11.4	

Note: Location of section shown on the mine map at (H); data shown graphically in Fig. 7H. Total thickness of bed, 6 ft. 11 in.

TABLE I

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Last Crosscut Between Main South and Back West

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
65	1	0	2.67	0.73	1.94	8.6	Two 1/8-in. streaks bone-coal.
64	1	10.5	2.75	0.70	2.05	5.7	One 1/4-in. band and 2 cat-faces 1 in. by 2 in., 1/2-in. mother-coal.
63		5.5	4.93	3.19	1.74	11.7	Coal taken 5 1/2 in. by 26 in. along lens of pyrite.
62	1	2	2.28	0.53	1.75	12.3	Two 1/8-in. bands bone-coal and 1/8-in. band mother-coal.
61	1	4	3.51	1.66	1.85	14.5	One 1/2-in. band and two 1/4-in. bands bone-coal.
60	1	1	4.85	3.24	1.61	12.5	1/8-in. band sulphur.
Average	.....		3.28	1.43	1.85	10.4	

Note: Location of section shown on mine map at (I); data shown graphically in Fig. 8I. Total thickness of bed, 7 ft. 1 in. Blue band is all pyrite here.

TABLE J

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Face of Fifth South, off First West South

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
39		11	5.13	3.58	0.97	2.88	1.55	10.1	
38	3	9	3.72	1.94	0.55	2.42	1.78	8.2	Two ⅛-in. bands and one ½-in. band pyrite; two ¼-in. bands bone-coal.
37	1	5	3.05	1.36	0.57	2.46	1.69	15.6	⅛-in. bone-coal and ⅛-in. pyrite.
36	1	0	7.15	5.68	0.80	2.68	1.47	20.2	½-in. band pyrite.
Average	.....		4.26	2.57	0.65	2.53	1.69	11.6	

Note: Location of section shown on mine map at (J); data shown graphically in Fig. 8J. Total thickness of bed, 7 ft. 1 in.

Table K

Forms of Sulphur in Sectional Samples

Middlefork Mine—Illinois Bed No. 6

Last Crosscut Between Seventh and Eighth South, off First West South Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
30		7.5	2.29	1.40	0.89	6.5	
29		8	3.85	2.97	0.88	10.1	One 1/8-in. band slate, pyrite lens 1 in. by 4 in.
28	4	0	1.94	1.07	0.87	8.5	Two 1/4-in. bands bone-coal and one 1/8-in. band mother-coal.
27		11	2.66	1.66	1.00	10.2	1 in. bone-coal, one 1/8-in. band pyrite.
26	1	0	1.74	0.77	0.97	8.6	
Average	.....		2.20	1.30	0.90	8.6	

Note: Location of section shown on mine map at (K); data shown graphically in Fig. 8K. Total thickness of bed, 7 ft. 2½ in.

Table L

Forms of Sulphur in Sectional Samples

Middlefork Mine—Illinois Bed No. 6

Tenth North, off First West South Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
35	0	5	4.28	3.03	1.25	7.5	
34	0	6	2.48	1.59	0.89	6.4	
33	5	3	1.57	0.75	0.82	8.0	1½ in. bone-coal and one ⅛-in. band mother-coal.
32	0	6	1.41	0.80	0.61	11.0	
31	0	7	1.14	0.57	0.57	9.8	31 and 32 below the blue band.
Average	.....		1.75	0.93	0.82	8.2	

Note: Location of section shown on mine map at (L); data shown graphically in Fig. 8L. Total thickness of bed, 7 ft. 3 in.

TABLE M

FORMS OF SULPHUR IN SECTIONAL SAMPLES

Middlefork Mine—Illinois Bed No. 6

Average of Bed for Various Locations

Values given in table in per cent, on a moisture-free basis

Section	Location	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash
1	10 N., 1 W. N.	3.88	2.12	1.76	13.3
2	7 N., 1 W. N.	3.72	1.82	1.90	11.1
3	4 N., 1 W. N.	4.82	3.17	1.65	13.2
4	Main North	4.24	2.88	1.36	11.6
5	3 N., 1 E. N.	4.08	2.95	1.27	11.5
age for	North Side.....	4.15	2.56	1.59	12.1
6	10 N., 1 E. S.	1.35	0.66	0.69	8.3
7	5 S., 1 E. S.	2.07	1.22	0.85	9.2
8	3 E. S.	4.01	2.15	1.86	11.4
9	Main South	3.28	1.43	1.85	10.4
10	5 S., 1 W. S.	4.26	2.57	1.69	11.6
11	7 S., 1 W. S.	2.20	1.30	0.90	8.6
12	10 N., 1 W. S.	1.75	0.93	0.82	8.2
age for	South Side.....	2.70	1.46	1.24	9.7
age for	Mine	3.30	1.92	1.38	10.7

West Kentucky Coal Co. No. 7 Mine, Kentucky No. 12 Bed.—
les N to S inclusive give the figures for the forms of sulphur in
sectional samples taken at the No. 7 mine of the West Kentucky
l Company. Corresponding letters are used to designate the
phs in the text, Fig. 11, N, O, P, Q, R, and S, which present the
e data and designate on the mine map, Fig. 12, locations at which
samples were taken. Table V gives the weighted average of the
ns of sulphur for the bed at the various locations in the No. 7
e.

West Kentucky No. 8 Mine, Kentucky No. 9 Coal.—Tables T and
ive the forms of sulphur in the sectional samples taken in the No. 8
e of the West Kentucky Coal Co. Fig. 13, T and U, show the
e data in graphical form.

Table N

Forms of Sulphur in Sectional Samples

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

First South, off Third Left Entry, off East Dip

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
18	1	0	3.86	2.97	0.89	8.54	One ¼-in. band pyrite, 2-in. band pyrite adjacent, but not included.
17	1	5	1.47	0.64	0.83	6.19	One ¼-in. band bone-coal.
16	1	5	0.89	0.15	0.74	8.96	One ¼-in. band mother-coal, one ½-in. band bone-coal.
15	1	4	0.90	0.11	0.79	6.77	
14	1	4	1.04	0.23	0.81	10.57	One 2½-in. band mother-coal and shale.
Average	.....		1.51	0.70	0.81	8.20	

Note: Total thickness of bed, 6 ft. 6 in. Top coal not sampled.

TABLE O

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

Fourth Left, off East Dip Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
13	1	5	0.69	0.05	0.64	5.32	One 1-in. band mother-coal.
12	1	5	0.73	0.10	0.63	7.76	One ½-in. band mother-coal.
11	1	5	0.94	0.35	0.59	22.59	1 in. mother-coal, one ½-in. band and one 1½-in. band soft shale; these are continuous shale bands of varying thickness.
10	1	5	0.95	0.23	0.72	5.58	One 1-in. band bone-coal at top of section.
9	1	4	1.59	0.77	0.82	8.50	One ⅛-in. band sulphur.
Average	.....		0.98	0.30	0.68	9.95	

Note: Total thickness of seam 7 ft. 0 in. Two feet of top coal which is commonly left up was not sampled.

TABLE P

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

Fifth Right Entry, off East Dip

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
23	2	6	2.14	1.28	0.74	1.69	0.86	7.24	Sample of top coal ordinarily left up for a roof.
22	1	6	1.17	0.49	0.41	1.02	0.61	8.68	Cat-face of sulphur 4 in. to one side of sample cut not included.
21	1	0	0.70	0.06	0.07	0.75	0.64	14.67	One ⅛-in. band, one ¼-in. band, and one ¾-in band mother-coal and shale.
20	0	9.5	0.97	0.34	0.27	1.14	0.63	28.01	One 2-in. band bone-coal, one ¾-in. band and one ½-in. band shale.
19	2	2	1.15	0.40	0.26	1.03	0.75	7.24	
Average	.....		1.39	0.65	0.42	1.21	0.74	10.4	

Note: Total thickness 7 ft. 11½ in. Top coal sampled.

TABLE Q

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

Cross-cut Between Rooms 8 and 9, Fifth South, off Third Left, off Main Rise

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
38	0	11	4.83	3.86	0.97	25.87	Sample of the top coal which is ordinarily left as a roof.
37	1	5	1.27	0.55	0.72	6.41	
36	1	1	0.91	0.19	0.72	9.75	
35	1	7	2.33	1.52	0.81	13.12	Two ⅛-in. bands pyrite; pyrite lens in edge of sample cut excluded.
34	1	6	2.65	1.81	0.84	9.98	One ¾-in. band bone-coal and one ¾-in. band sulphur.
Average	.....		2.29	1.49	0.80	12.1	

Note: Total thickness of bed, 6 ft. 6 in. Top coal sampled.

TABLE R

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

Face of Fourth Right Entry, off Main Rise

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur	Organic Sulphur	Ash	Remarks
28	1	0	1.86	0.96	0.90	7.85	
27	1	0	1.12	0.36	0.76	7.18	
26	1	0	1.00	0.18	0.82	5.80	One 1-in. band bone-coal; one ¼-in. band shale.
25	1	0	1.02	0.16	0.86	7.07	One ⅛-in. sulphur band.
24	0	10	1.57	0.62	0.95	9.16	One ¼-in. band of mother-coal.
Average	.....		1.30	0.45	0.85	7.35	

Note: Total thickness of bed, 4 ft. 10 in. 2 ft. 0 in. of top coal not sampled.

TABLE S

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 7—Kentucky Bed No. 12

Room 23 Top, off Main Rise Entry

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
33	1	1	2.27	1.40	0.16	1.04	0.87	7.10	
32	1	2	1.28	0.48	0.35	1.17	0.80	7.16	
31	1	1	1.07	0.26	0.19	1.04	0.81	7.82	One ¼-in. band mother-coal and one ¼-in. band bone-coal.
30	1	2	1.01	0.24	0.23	1.00	0.76	4.32	One ¾-in. band mother-coal and one ¼-in. band bone-coal.
29	1	5	1.52	0.63	0.37	1.39	0.89	7.13	
Average	.....		1.43	0.60	0.27	1.14	0.83	6.71	

Note: Total thickness of bed, 5 ft. 11 in. One foot of top coal not sampled.

TABLE T

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 8—Kentucky Bed No. 9

Face of Tenth East Entry, off the Main Dip

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
4	1	3	2.46	0.72	0.41	2.18	1.74	11.59	One ½-in. and one ¼-in. band of sulphur.
3	1	3	3.02	0.98	0.39	2.45	2.04	6.20	Two ⅛-in. bands, and one ¼-in. band of mother-coal and one ⅛-in. band sulphur, one 1½-in. band sulphur discarded.
2	1	3	3.45	1.73	0.94	2.74	1.72	11.77	One ⅛-in. band sulphur.
1	1	3	5.13	3.59	1.76	3.70	1.54	15.93	Two ⅛-in. bands pyrite.
Average	.....		3.51	1.75	0.88	2.77	1.76	11.37	

Note: Total thickness of bed, 5 ft. 0 in.

TABLE U

FORMS OF SULPHUR IN SECTIONAL SAMPLES

West Kentucky Coal Co., Mine No. 8—Kentucky Bed No. 9

Face of Tenth West Blind Entry, off the Main Dip

Values given in table in per cent, on a moisture-free basis

Sample No.	Vertical Thickness Ft.	Vertical Thickness In.	Total Sulphur	Pyritic Sulphur		Total Sulphur Float 1.40	Organic Sulphur	Ash	Remarks
				Total	Fine				
8	1	3	2.33	0.50	0.25	2.19	1.83	8.90	
7	1	3	4.11	2.15	0.73	2.74	1.96	8.72	Two ¼-in. bands sulphur and one ⅛-in. band mother-coal included.
6	1	3	2.83	0.86	0.45	2.83	1.97	8.03	
5	1	5	4.28	2.57	0.82	2.64	1.71	13.05	One ¼-in. band sulphur and one ¼-in. band mother-coal included.
Average	.....		3.42	1.55	0.57	2.61	1.86	9.85	

Note: Total thickness of bed, 5 ft. 2 in.

Table V

Forms of Sulphur in Sectional Samples

West Kentucky Coal Co., Mines Nos. 7 and 8—Kentucky Beds Nos. 12 and 9

Average of Beds for Various Locations

Values given in table in per cent, on a moisture-free basis

Location	Total Sulphur	Pyritic Sulphur		Total Sulphur Float on 1.40	Organic Sulphur	Ash
		Total	Fine			
Mine No. 7:						
R.02: 4th L: E. Dip	0.98	0.30	....	....	0.68	9.95
R.2: 1st S: 3d L: E. Dip	1.51	0.70	....	....	0.81	8.20
R.20: 5th R: E. Dip	1.39	0.65	0.42	1.21	0.74	10.4
4th R. Main Rise	1.30	0.45	....	....	0.85	7.35
23 Top Rm. Main Rise	1.43	0.60	0.27	1.14	0.83	6.71
5th S: 3d L: Main Rise	2.29	1.49	....	....	0.80	12.1
Average	1.48	0.70	0.34	1.17	0.78	9.12
Mine No. 8:						
10th East Main Dip	3.51	1.75	0.88	2.77	1.76	11.37
10th West Main Dip	3.42	1.55	0.57	2.61	1.86	9.85
Average	3.46	1.65	0.73	2.69	1.81	10.61

APPENDIX II

Sink and Float Tests

ink and Float Tests on Bench Samples.—Tables 11, 12, and e the results of sink and float tests on the samples taken at two in the No. 7 mine, two places in the No. 8 mine, and four places Middlefork mine. A zinc chloride solution of a specific gravity) was used and the samples were crushed to ¼-in. maximum size. his test is often used as a preliminary washing test. The pro- n of float coal and its ash and sulphur content give a general tion of what may be recovered as washed coal. The sink and est gives a more perfect gravity separation than the commercial ashing methods. For that reason washing can not be expected ult in both as high recovery of washed coal and as great a re- n in impurities as the sink and float test. It approaches these more or less closely, depending upon the efficiency and suitabil- the process used.

solution of 1.35 specific gravity is more commonly used for st, but this is varied to suit the characteristics of the coal. In se a solution of 1.35 specific gravity gave an unwarrantably roportion of sink. The specific gravity of two representative . samples of this coal from the No. 7 mine, determined by a tric method, were 1.319 and 1.313. The specific gravity of a site sample of the Middlefork coal including all samples on sink and float tests were made was 1.325. A solution of 1.35 gravity was considered too close to this figure to be suitable sink and float test.

ne float coal of sample 20 from the No. 7 mine was considerably in sulphur content than the raw coal; this is explained by ct that the sample contained a large amount of ash in the of coarse shale bands. The sink and float test therefore re- in the removal of a large amount of heavy inorganic matter was low in sulphur, leaving the sulphur concentrated in the oal. The sink amounted to 46.6 per cent of the sample and only 0.66 per cent sulphur, while the sulphur content of al was 0.97 per cent. Similar results are sometimes secured in ashing practice for the same reason.

TABLE 11

SINK AND FLOAT TESTS ON SAMPLES FROM MINE NO. 7, WEST KENTUCKY COAL CO.

At 0-in. to ¼-in. size, on solution of 1.40 sp. gr.

Values given in table in per cent, on a moisture-free basis

Original Sample						Float Coal		Location in Mine from Which Sample Was Taken
No.	Weight Gms.	Sulphur	Ash	Sink	Float	Sulphur	Ash	
23	270	2.14	7.24	10.4	89.6	1.69	6.95	Room 20, 5th R., East Dip.
22	333	1.17	8.68	11.9	88.1	1.02	6.36	
21	342	0.70	14.67	27.0	73.0	0.75	7.72	
20	333	0.97	28.01	46.6	53.4	1.14	8.44	
19	338	1.15	7.24	8.6	91.4	1.03	5.35	
Weighted average		1.39	10.40	15.8	84.2	1.21	7.4	
33	342	2.27	7.10	3.8	96.2	1.04	5.50	23 top room, Main Rise.
32	363	1.28	7.16	3.9	96.1	1.17	6.36	
31	349	1.07	7.82	15.9	83.1	1.04	5.30	
30	299	1.01	4.32	5.4	94.6	1.00	3.28	
29	325	1.52	7.13	6.8	93.2	1.39	5.26	
Weighted average		1.43	6.71	5.8	94.2	1.14	5.06	

TABLE 12

SINK AND FLOAT TESTS ON SAMPLES FROM MINE NO. 8, WEST KENTUCKY COAL CO.

At 0-in. to ⅛-in. size, on solution of 1.40 sp. gr.

Values given in table in per cent, on a moisture-free basis

Original Sample						Float Coal		Location in Mine from Which Sample Was Taken
No.	Weight Gms.	Sulphur	Ash	Sink	Float	Sulphur	Ash	
4		2.46	11.59	6.6	93.4	2.18	8.10	10 E., Main Dip.
3		3.02	6.20	4.0	96.0	2.45	4.00	
2		3.45	11.77	7.9	92.1	2.74	8.05	
1		5.13	15.93	18.4	81.6	3.70	12.00	
Weighted average.....		3.51	11.37	9.2	90.8	2.77	8.06	
8		2.33	8.90	3.0	97.0	2.19	8.49	10 W. Blind, Main Dip.
7		4.11	8.72	6.3	93.7	2.74	4.30	
6		2.83	8.03	3.8	96.2	2.83	5.15	
5		4.28	13.05	11.9	88.1	2.64	8.95	
Weighted average.....		3.42	9.85	6.4	93.6	2.61	6.78	

TABLE 13

SINK AND FLOAT TESTS ON SAMPLES FROM THE MIDDLEFORK MINE

At 0-in. to ¼-in. size, on solution of 1.40 sp. gr.

Values given in table in per cent, on a moisture-free basis

Original Sample						Float Coal		Location in Mine from Which Sample Was Taken
No.	Weight Gms.	Sulphur	Ash	Sink	Float	Sulphur	Ash	
5	468	5.47	13.3	18.0	82.0	3.42	5.13	Face of Fourth North off the First West North Entry.
4	524	4.60	9.5	9.2	90.8	2.99	4.09	
3	417	3.70	11.2	17.3	82.7	2.44	5.17	
2	516	4.32	17.2	26.8	73.2	2.87	10.11	
1	431	7.55	18.0	39.0	61.0	3.17	8.01	
39	541	5.13	10.1	25.5	74.5	2.88	5.40	Face of First South off the First West South Entry.
38	471	3.72	8.2	13.6	86.4	2.42	3.75	
37	445	3.05	15.6	34.8	65.2	2.46	8.08	
36	403	7.15	20.2	33.8	66.2	2.68	8.15	
15	526	6.36	19.0	17.4	82.6	2.67	5.10	Tenth North, First West North Entry.
14	453	3.15	7.6	8.8	91.2	2.60	3.25	
13	462	3.16	10.8	12.5	87.5	2.36	5.53	
12	491	3.97	17.9	30.6	69.4	2.64	10.07	
11	532	4.90	15.4	26.0	74.0	3.03	7.78	
25	442	3.13	7.7	6.6	93.4	1.81	4.90	Fifth South, First East South Entry.
24	455	1.40	8.0	7.9	92.1	1.44	3.15	
23	469	3.09	6.5	7.5	92.5	1.50	3.40	
22	468	1.51	11.1	16.0	84.0	1.41	6.46	
21	446	2.59	10.5	12.7	87.3	1.95	6.30	